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A STUDY OF TWO AVIONICS LIFE CYCLE COST MODELS AND THEIR APPLIC--ETC(U)
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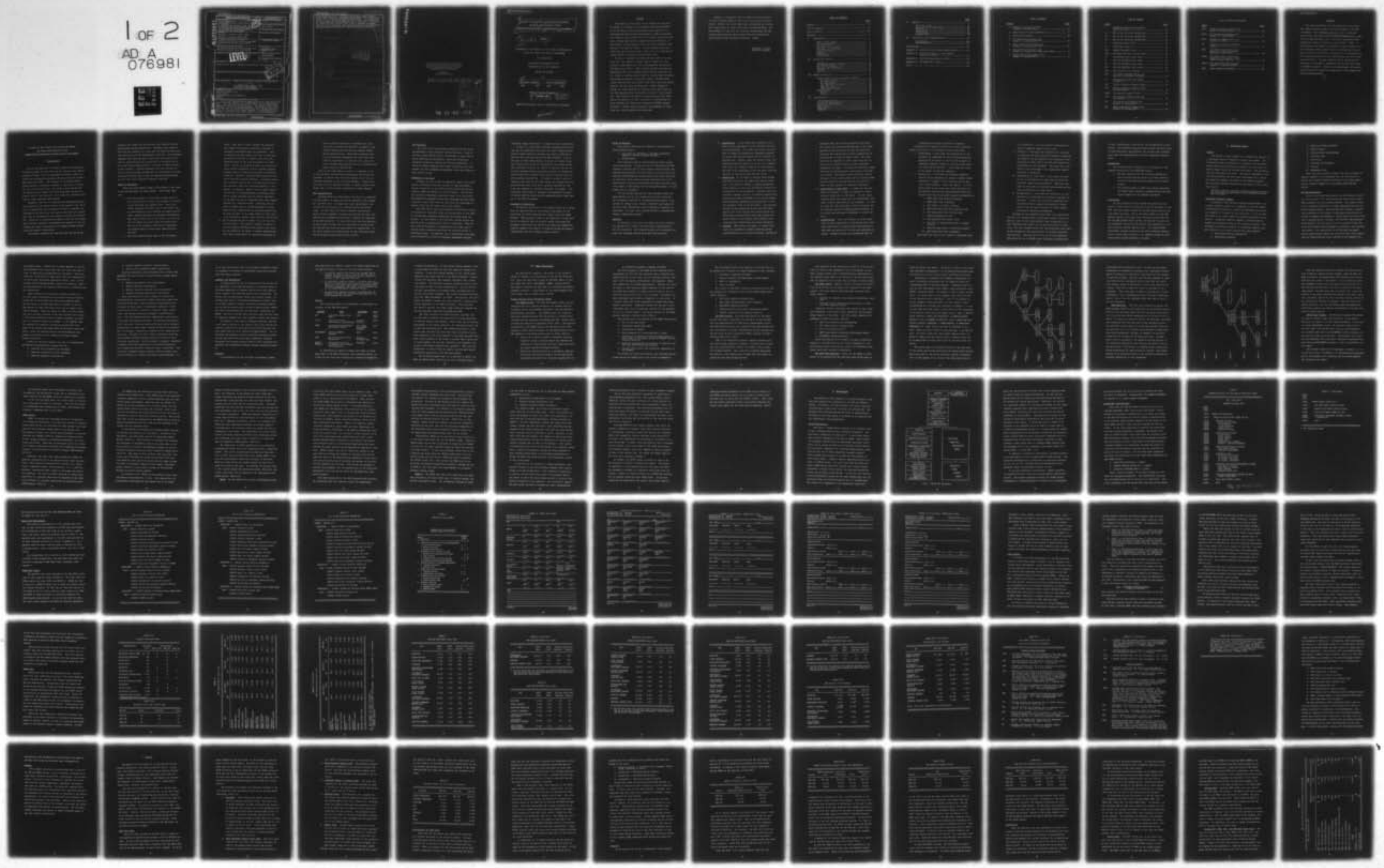

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFIT/GSM/SM/79S-5	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A STUDY OF TWO AVIONICS LIFE CYCLE COST MODELS AND THEIR APPLICABILITY IN THE COMMUNICATIONS-ELECTRONICS-METEOROLOGICAL ENVIRONMENT		5. TYPE OF REPORT & PERIOD COVERED M.S. Thesis
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Nicholas J. Drobot, Capt, USAF; Martin H. Johnson, Capt, USAF		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Air Force Institute of Technology (EN) Wright-Patterson AFB, Ohio 45433		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Institute of Technology (EN) Wright-Patterson AFB, Ohio 45433		12. REPORT DATE September 1979
		13. NUMBER OF PAGES 156
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

LEVEL II

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

DDC
NOV 7 1979
RECEIVED
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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Approved for public release; IAW AFR 190-17

Joseph P. Hipps, Major, USAF
Director of Information

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Life Cycle Cost
Logistic Support Cost
Cost Models
Communications Cost Modeling
Models

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This study determines the applicability of Life Cycle Cost (LCC)/ Logistic Support Cost (LSC) models in the CEM environment. The study was initiated with a literature search which identified several promising models. The scope of this study addresses two of the models identified (LSC, PRICE) with respect to three Air Force TACAN systems. A methodology is developed to evaluate each model based on the five desirable

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THESIS

AFIT/GSM/SM/79S-5

Nicholas J. Drobot, Capt, USAF
Martin H. Johnson, Capt, USAF

14 AFIT/GSM/SM/79S-5

6 A STUDY OF TWO AVIONICS LIFE CYCLE COST MODELS

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COMMUNICATIONS-ELECTRONICS-METEOROLOGICAL ENVIRONMENT

9 Master's THESIS

Presented to the Faculty of the School of Engineering

of the Air Force Institute of Technology

Air University

in Partial Fulfillment of the

Requirements for the Degree of

Master of Science

by

10 Nicholas J. Drobot Martin H. Johnson

Capt USAF Capt USAF

Graduate Systems Management

11 September 1979 12 57

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Preface

This thesis is the result of our efforts for the past six months to evaluate two cost models currently available in the Air Force avionics environment with regard to the Communications-Electronics-Meteorological (CEM) environment. This study not only taught both of us a great deal about life cycle costing and logistics support costing techniques, it also taught us about aspects of the Air Force community that neither of us had seen before. We also learned about ourselves and how we could tackle a task a bit at a time and actually finish a seemingly insurmountable task.

We wish to express our thanks and gratitude to our advisor, Lt. Col. Edward J. Dunne, and our reader, Lt. Col. Richard V. Badalamente for their encouragement and guidance throughout this effort. Major William Donahue and numerous Headquarters Air Force Communications Service personnel and Mrs. Diane E. Summers and her staff at the Air Force Avionics Laboratory all deserve a heartfelt thanks. Without their support and interest this effort would never have even gotten started. We also must say thank you to Ssgt. Michael R. Downey, Mr. James Walther and numerous other individuals at the 2046 Communications Installation Group for their expertise. They answered our numerous inane questions and freely shared the benefits of their experience in maintaining Air Force Terminal Air Control and Navigation (TACAN) systems worldwide. Without their assistance and expertise we never would have even finished collecting data.

Finally, we especially wish to thank our wives and families for standing behind us and with us for the past fifteen months. Without our wives expert eyes to decipher our unreadable rough drafts we never would have finished anything. How they managed to cope with the children, housekeeping and typing and still maintain their sanity while we studied we'll never know but they did and we finished. Thanks.

Nicholas J. Drobot
Martin H. Johnson

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Abstract

This study determines the applicability of Life Cycle Cost (LCC)/ Logistic Support Cost (LSC) models in the CEM environment. ~~The study was~~ initiated with a literature search which identified several promising ~~models.~~ The scope of this study addresses two of the models identified (LSC, PRICE) with respect to three Air Force TACAN systems. A methodology is developed to evaluate each model based on the five desirable model characteristics: availability of input data, validity, sensitivity, completeness, and documentation. The results presented are also framed within the above model characteristics. The most important model characteristic, validity, is accessed by comparison with an AFCS cost study of NAVAIDs equipment. Based on the methodology, the results indicate that both models are applicable in the present and future CEM environment.

A STUDY OF TWO AVIONICS LIFE CYCLE COST MODELS
AND THEIR APPLICABILITY IN THE
COMMUNICATIONS-ELECTRONICS METEOROLOGICAL ENVIRONMENT

I Introduction

Due to the high costs of defense systems both during the acquisition phase of their life and the operation and support portions of their life, all Department of Defense (DOD) personnel are becoming increasingly concerned about any system's Life Cycle Cost (LCC). LCC analysis of a proposed system should provide a reasonable estimate of the cost of a system for its life or life cycle. LCC analysis also can provide the analyst with a better idea concerning which system components can be "cost drivers" due to high cost, frequent failures or other component difficulties.

Generally, the cost of operating and supporting any system accounts for the major portion of the system's life cycle cost. Consequently when discussing the LCC of a system, the ownership costs associated with system operations and support must also be considered in any attempt to reduce the system's LCC. Reduction in operating and support costs can be brought about through increased consideration and analysis of the operating and support implications of proposed design alternatives and support alternatives.

The defense industry has indicated that the use of LCC

analysis must range from the smallest scale project through major weapon systems acquisition. Industry, also, seems to feel that LCC analysis is a good idea but should be paid more than lip service by the DOD (Bennett, 1976:38). The increased emphasis that industry feels is required could take on the form of incentives paid to contractors for providing equipment with design characteristics in excess of those required by the contract. Industry spokesmen have also pointed out that in some instances although LCC was identified as a major selection criteria that it was not weighted heavily enough in the final source selection (Bennett, 1976:38).

Types of LCC Models

There are three general types of LCC models in use today in the United States Air Force (USAF). These model types are:

1. Cost Factor Models — This type of model uses Air Force derived cost factors in an attempt to estimate system operating and support costs. Cost factor models typically estimate costs at the system level by identifying such cost elements as spares requirements, support equipment and manpower requirements. This type of model can be used easily, but since it does not break costs down below the system level may not be as accurate a predictor of operations and support costs as other model types (Collins, 1976:54).
2. The second general model type is the accounting

model. This type of model computes the operation and support cost portion of LCC as a function of equipment and program logistics parameters. This is probably the most widely used type of model and typically can be used to compute costs below the subsystem level to the Line Replacable Unit (LRU) level. In use, an accounting model will usually require several categories of data including program elements such as flying hour programs or deployment scenarios, contractor furnished LRU elements and Air Force furnished constant elements. Accounting models can usually be used as one of several source selection criteria either for an entire system or a subsystem, as required. However, due to model complexity and lack of standardization, accounting models can be rather unwieldy and cost figures generated by one model may not be comparable with cost figures computed by a different model. Intricacy also becomes a problem when an accounting model is being used for cost computations for an entire system due, at least in part, to the large number of input data items required to compute costs (Collins, 1976:55-57).

3. The third general type of model in use is the optimization model. This general category of models is used to optimize operations and support costs based on some subset of the range of support alternatives. This class of LCC models is currently being used in

some Air Force situations to determine the least cost level of repair for defective equipment, maintenance manning policies and also optimal spares provisioning policies. Maintenance manpower policies and inventory management are areas where substantial reductions in a system's life cycle cost can be brought about through the use of optimization models (Collins, 1976:57-59).

Each of the above types of models is currently in use in the Air Force and DOD assisting managers and acquisition personnel to procure cost effective systems and to utilize existing resources in cost effective manners. A great deal of effort is still required however, to refine current techniques and to allow for LCC reductions in future systems.

LCC Considerations

Although there are difficulties involved it is important for LCC analysis to begin as early as possible in the stages of a system's life. In almost all cases the greatest cost savings for any system can be incurred during the design stage. At this time such items as modular construction, built-in-test equipment, increased reliability and lower complexity can be addressed and provide a significant opportunity for LCC reductions. It should be noted that consideration of these types of items does not guarantee an overall lower LCC instead they offer the opportunity for lowering LCC. In the final analysis user applications in the field will drive the LCC actually experienced (Eaton, 1977:3).

LCC Reduction

In a life cycle cost analysis reductions in LCC can be accomplished in many different interrelated ways. Some of the most common methods used in attempting to reduce LCC include improving maintainability, improving reliability, changing maintenance concepts and reducing complexity. It should be readily apparent that these methods are not independent but that changing one parameter could very likely affect another factor.

Statement of the Issue

Although the use of LCC and logistics support cost (LSC) models is becoming relatively routine in USAF procurement actions, their use in the Communications-Electronics Meteorological (CEM) environment is not yet routine. LCC and LSC are becoming increasingly important issues in all Air Force procurements as managers become more concerned not only about a system's acquisition cost but also about the operating and support costs for the entire life of the system.

Each time that a major procurement or modification action is initiated an extensive delay can develop while a cost model is located that adequately represents the system being considered. If this search is not fruitful, further delays will develop while a representative model is developed. These delays could be minimized if a generalized cost model were available which accurately predicted the relative merits of competing systems. In addition, such a generalized cost model could potentially be used in subsequent management analysis

comparing design alternatives or support policy alternatives.

As part of a long range strategic planning effort focusing into the 1985-1995 time frame, Air Force Communications Service (AFCS) logistics planners are keenly interested in reducing the costs associated with CEM equipment. Some of the ways in which AFCS planners envision cost models being used include such issues as alternatives for fielded equipment (continue to use as is, modify or replace) and also to evaluate proposed system development options or maintenance options and even to decide which system to procure from competing design alternatives. In order to build or modify a computer cost model to fit their needs cost analysis and program personnel must first gain a greater awareness of the scope and adequacy of currently available cost models. Consequently, AFCS logistics planners are interested in state-of-the-art LCC/LSC models and the applicability of these models to the CEM environment.

Statement of Objectives

The specific objective of this thesis effort is to determine the applicability of two existing cost models to the prediction of future operating and support costs for TACAN Systems. AFCS planners intend to use applicable LCC/LSC models as an analytic tool in decision issues concerning CEM equipment acquisition and modification where the comparative logistic support cost impacts of proposed design and support alternatives will be a primary decision factor.

Scope of Research

This thesis effort will be limited to an evaluation of the following models:

1. LSC (which is included in the SAVE interactive graphics computer software package)

2. PRICE/PRICE-L

This research looks at two existing Air Force navigational aid systems. It was felt by the researchers and CEM logistics planners that if this current research effort were widened beyond systems for which AFCS has sole Air Force Operations and Maintenance responsibility that data collection of historical costs would be nearly impossible due to the difficulties involved in discovering all DOD activities using other types of CEM systems such as air-ground radios, or telecommunications equipment.

The two systems selected for this research effort are TACAN Systems and all are located at Air Force airfields. The widespread locations of the TACAN Systems exposes these systems to virtually all climatic conditions and supply difficulties that CEM systems could reasonably be expected to experience. As such, these systems provide a representative sample of CEM system support.

Approach

In choosing a life cycle cost model for use in predicting system costs, several desirable model characteristics will be considered. The characteristics to be considered include the following (Course Notes QM 5.99:8.16-8.17):

1. Completeness. A cost model must include all elements of cost appropriate to the decision issue under consideration. If a total life cycle cost estimate is needed for planning or budgetary purposes, the model must include essentially all elements of program cost. However, when the decision under consideration does not affect all of the cost elements, only those cost elements affected by the decision may need to be considered in the cost model used for analysis of that particular decision issue.

2. Sensitivity. To be useful in design trade studies and other decisions, the model used must be sensitive to the specific design of program parameters being studied, so that cost differences between the alternatives can be determined. Although this characteristic appears obvious, it remains a significant problem since many LCC models do not include design and performance parameters associated with systems and equipment found in the Air Force. This problem becomes further aggravated by the fact that many types of Air Force systems have unique design and performance characteristics which may require different models so that design trade studies can be conducted when alternatives are being considered.

3. Validity. When using a LCC model to compute life cycle cost differences between differing design characteristics as a decision criterion, one must be

confident that the results generated by the model are in fact an accurate representation of the costs expected in the real world or that the costs predicted by the models yeild accurate comparisons of alternatives in terms of higher costs. The model used must be examined to ensure that costs are arrived at in a logical manner and are consistent throughout the model. It should be noted that judgement must be exercised when considering a cost model's output. The analyst should check the reasonableness of the results particularly in design trade studies where the results could be utilized as a basis for LCC analysis or production decisions.

4. Availability of Input Data. In order for any cost model to be useful, it must be feasible to obtain accurate input data for the model. In some cases, otherwise good cost models are of questionable value since accurate input data is not available. In other cases the input data may in fact be accurate but not readily available causing extreme workloads to be placed upon personnel attempting to collect the data.

5. Documentation. Since cost models can differ radically in their approaches to determining life cycle costs there must be adequate model descriptions so that work can quickly be reviewed and understood by others. Analysis methods and assumptions must be

documented and readily available to analysts.

In assessing the models for each of the five characteristics listed above, the following criteria were used:

1. Completeness — each model was assessed as to completeness by comparing the cost elements/categories addressed by the model to the ten cost elements of integrated logistic support as defined in DOD directive 4100.35G and AFP 800-7. Each model was rated by the number of elements addressed.

2. Sensitivity — each model was assessed regarding sensitivity by comparing the changes in model output variables to changes in the following list of specific input variables. These are typical input variables which would change when using the model for the purposes intended (procurement/modification decisions involving design and/or support alternatives):

    1. MTBF (Mean Time Between Failures)
    2. MTTR (Mean Time to Repair)
    3. RIP (Repair in Place) fraction
    4. NRTS (Not Repairable This Station) rate
    5. RTS (Repairable This Station) rate
    6. COND (Condemnation) rate
    7. EBO (Expected Back Order) level
    8. CAD (Cost of Maintaining Parts in Supply System)
    9. ANPR (Average Number of Parts Per Repair)
    10. DMH (Depot Mean Time to Repair).

    Each model was rated by the number of variables that

it is sensitive to and the relative sensitivity of overall logistics support cost to each.

3. Validity — each model was assessed as to validity by comparing the model generated logistics operating and support cost per system to the historical costs developed in April 1979 by HQ AFCS DCS Comptroller, Directorate of Cost Analysis. Each model was rated based on the percentage of the experienced support cost that it predicted.

4. Availability of Input Data — each model was assessed as to availability of input data by reviewing the model input data requirements. Each model was rated by the number of required data sources and the data availability from each source.

5. Documentation — each model was assessed as to documentation by examining the available literature on the model. A model which could be understood and exercised without a significant amount of direct contact with the model developer or other analyst was rated as adequately documented.

Although it was recognized that these five characteristics are all important when considering a models overall usability, some of the characteristics were recognized to be more important than others for the decision issues in question. For this research effort the characteristics were ranked and weighted in the determination of a models potential applicability. Validity was felt to be the most important characteristic for a LCC/LSC model followed by Availability

of Data, Completeness, Sensitivity, and Documentation respectively. For comparison purposes after a model had been rated on each individual characteristic the results were weighted based upon the characteristics relative importance depicted above.

Assumptions

The following basic assumptions are necessary in this study's evaluation of the PRICE/LSC models:

1. The data obtained from the Air Force Maintenance Data Collection System gives an accurate representation of the maintenance performed on the systems studied.
2. Cost data generated by AFCS cost analyst personnel for sample bases provides a representative cost population sample for the systems considered.

Limitations

In this research we have limited the search for cost models to those that are currently in use or available in the DOD. We were further limited by the LRU concept used in the cost models selected. Due to the small number of like CEM systems located on a single base (usually not more than two for any CEM system) these systems are repaired in place (on the equipment) and not by LRU removal and replacement as aircraft avionics systems typically are. The current TACAN maintenance concept, prescribed by system technical publications, forced input variables to be explicit values to accurately model system maintenance concepts.

II Literature Search

Purpose

The purpose of this chapter is to present the results of a literature search of logistics support cost models. The literature search was initiated to determine if cost models existed that would realistically compute the life cycle logistics support costs in the CEM environment. The hypothesis was that such models did exist. Proving the hypothesis to be true would preclude the full scale development of a totally new logistics support cost model for the CEM environment. The following statement defines the objectives of the literature search:

> Identify currently available logistics support cost models that might be applicable in the present and future CEM environment.

Integrated Logistic Support

As defined in DOD directive 4100.35G and AFP 800-7, integrated logistic support is a composite of all the support considerations necessary to assure the effective and economical support of a system for its life cycle. It is an integral part of all other aspects of system acquisition and operation. Integrated logistic support is characterized by harmony and coherence among all the logistic elements. The principal interrelated elements of integrated logistic support related to the overall system life cycle include:

1. Maintainability and Reliability
2. Maintenance Planning

3. Support and Test Equipment
4. Supply Support
5. Transportation and Handling
6. Technical Data
7. Facilities
8. Personnel and Training
9. Funding
10. Management Data

Since the above elements comprise the major elements of logistic support to be considered over the life cycle of a system, the elements should be included in any model depicting the logistic support of a new system (DOD 4100.35G, 1968:7).

The CEM Environment

Since a cost model must address the environment in which it is to be used, it is worth noting the trend in the future CEM environment as seen by AFCS planners. The future outlook is for continued reductions in budget appropriations and personnel authorizations. AFCS planners are looking at significant reductions in the number of maintenance specialties required to support new equipment. AFCS planners are also looking to acquire proven, existing, off-the-shelf CEM equipment. By definition, the life cycle cost of a system includes the costs for research and development, acquisition, and operation and support. The acquisition of off-the-shelf equipment should significantly reduce the life cycle cost of new equipment by eliminating the costs incurred in the research and

development phase. Greater use of proven designs in off-the-shelf equipment will also reduce the life cycle cost when it comes to operating and supporting new equipment. Proven designs are, by definition, those which have been developed and for which some operational experience exists. Thus, on the average, proven designs promise improved reliability, improved maintainability, and improved efficiencies in required support operations.

When looking at off-the-shelf equipment reliability, the most unique consideration receiving increasing attention within DOD is the Reliability Improvement Warranty (RIW). The key issue in the RIW application is whether or not the RIW results in lower life cycle costs than an organic maintenance program. Under the terms of a RIW, all line replaceable unit failures verified at the base (system) level using a relatively inexpensive item of support equipment are shipped to a contractor depot for repairs. It is expected that the majority of a system's reliability growth will occur early in the system life cycle while the system is under warranty. After the warranty period, system maintenance and support are picked up by an organic maintenance program (Gates, 1976:3-42).

Future off-the-shelf designs will also be characterized by improved maintainability brought about by:

1. Improved test equipment and procedures
2. Improved reliability of test equipment
3. Improved equipment accessibility

4. Greater support equipment standardization

5. Built In Test Equipment (BITE) capabilities

Improved reliability and maintainability of future CEM equipment will also result in more efficient support operations due to:

1. Reduced maintenance skill requirements

2. Reduced manpower requirements

3. Reduced logistics pipeline time requirements

4. Reduced scheduled maintenance requirements

When considering the future changes in reliability, maintainability, and required support operations, AFCS planners have envisioned a 1990 maintenance organization characterized by three types of maintenance personnel: Fault isolation specialists, electronic component repair technicians, and overhead personnel (managers, administrators, etc.). The resulting maintenance organization would require a two-level maintenance sturcture. At the first maintenance level, the fault isolation specialists would detect equipment malfunctions and would repair systems by removal and replacement of equipment components or modules at the operating system level. Personnel on their initial enlistment receiving short systems oriented training would be utilized as fault isolation specialists. Failed equipment, equipment components or modules would be transported to the second maintenance level manned by electronic component repair technicians. The electronic component repair personnel would be career technicians working at a central maintenance depot/location. It

is at this maintenance level that equipment components would be condemned or repaired to operational status and recycled into the spares pipeline.

Approach and Methodology

In approaching the task of identifying existing LSC models applicable in the CEM environment a literature search of pertinent Department of Defense and Air Force (AF) publications, studies, and technical reports was accomplished. The search also covered student theses and research papers. Inquiries were made to the Defense Documentation Center (DDC), the Defense Logistics Studies Information Exchange (DLSIE), and the National Aeronautics and Space Administration (NASA). The source contributing the most pertinent information was DLSIE. The above searches were initiated under the key terms of "logistic support cost" and "logistic support cost models".

In addition to the strict literature searches, key personnel were contacted in the areas of life cycle costing and logistics support cost modeling from Air Force Systems Command (AFSC) and Air Force Logistics Command (AFLC). The information and guidance received from AFSC and AFLC personnel was the most useful and up-to-date information obtained throughout this research project and not only reinforced but augmented the information obtained through literature searches.

Criteria

In reviewing all of the available information, models

were identified as logistic support cost models applicable in the CEM environment if they met the following criteria:

1. A logistic support cost model must account for or compute the cost of all or some of the ten inter-related elements of integrated logistic support as defined in DOD directive 4100.35G.

2. An applicable logistic support cost model must address or be sensitive to at least some of the unique aspects of the future CEM support environment (off-the-shelf-equipment, RIW, BITE, possible variations in the system/equipment indenture levels).

3. An applicable logistic support cost model must be general in nature and not solely applicable to airborne systems and aircraft.

<u>Results</u>

The following models were identified as potentially applicable in the CEM environment:

ACRONYM	NAME	DEVELOPER	YEAR
LSC	Logistics Support Cost Model	AFLC	1973 1976
LCC-2	Life Cycle Cost 2 (Operations, Maintenance)	Analytic Science	1976
GEMM	Generalized Electronics Maintenance Model	U.S. Army Electronic Command	1971
MOD-METRIC	Modified METRIC Program	AFLC	1972
SAVE	Systems Avionics Value Estimation	Battelle Columbus Lab	1977
PRICE/ PRICE L2	Programmed Review of Information for Costing and Evaluation	RCA/AFAL	1978

In identifying a logistic support cost model as being applicable in the CEM environment, the screening process involved via the first two criteria was a matter of inspection

of model documentation. It was fairly obvious whether or not a given model accounted for specific logistics support cost elements. It was also obvious whether or not a given model addressed the unique aspects of the CEM environment. Approximately 200 abstracts were examined throughout this literature search. The abstracts examined summarized actual existing models or model related documentation. From the 200 abstracts, approximately 20 complete model documents were requested and further examined. The models eventually selected were LSC, GEMM, MOD-METRIC, and SAVE. Additionally, the LCC-2, PRICE, and PRICE L2 models were also selected as being potentially applicable in the CEM environment. This selection was based on general cost model usage experience imparted by the key personnel contacted from AFSC and AFLC.

The third criterion for model selection required that the LSC model be general in nature and not solely applicable to airborne systems and aircraft. While there was no detailed application of the third criterion, the researchers would like to make the following note. Most authors/developers of LSC models that satisfied the first two model selection criteria made reference to the word "system" in the model documentation. When citing examples of the kinds of systems that a given model could address, the two most frequently used examples were aircraft and ground communications equipment. This lead the researchers to believe that the models selected were indeed potentially applicable in the CEM environment.

The following chapter goes on to describe in detail the SAVE and PRICE models identified by this literature search.

III Model Description

As indicated in chapter I, the scope of this research effort is limited to an evaluation of the LSC and PRICE models. Since the LSC model is part of the SAVE family of models (CACE, LSC, LCC-2, MOD-METRIC, GEMM), initial efforts were made to evaluate the LSC model via the SAVE interactive computer software. A description of the SAVE computer software package and the PRICE models follows.

System Avionics Value Estimation (SAVE)

The SCALE Project. The SAVE development effort was preceeded by (and is a logical extension to) another model development effort called SCALE (Systematic Cost and Logistics Effectiveness Procedure). The SCALE project was conducted from July through November 1975 by Battelle's Columbus Laboratories and was sponsored by Headquarters AFLC, Deputy Chief of Staff for Acquisition Logistics (Cork, 1975). The approach and results of the SCALE project are covered at this point because of their direct relevance to the SAVE research effort. The purposes of the SCALE project were to (Cork, 1973:3):

1. Conduct an extensive review of currently available logistics support planning models and identify the interface of those models with each other and within the weapon system development process.
2. Define the characteristics of a systematic approach with which the available models can be made easily accessible and usable for iterative applications via

an interactive graphics computer processor.

The first purpose of the SCALE project resulted from a realization in 1975 that the available models examined individual portions of the total cost of ownership such as inventory, level of repair, effectiveness, and manpower. There was a great deal of overlap among models. However, the level of detail in each area was highly dependent on the function the model was intended to support and the stage of the acquisition process for which it was intended. The models had been developed almost totally independent of each other. As a result, there was little commonality in input data units, format, and detail. Guidelines existed for the use of each individual model but no guidelines existed for the synergistic use of selected models. The second purpose of the SCALE project logically followed (Cork, 1975:2).

The primary goals and features of the SCALE concept were:

1. Use of existing models
2. Consistent input/output data
3. Interaction of models
4. Quick response by a broad spectrum of users
5. Hierarchial framework for relevant application at each stage of the weapon system development and subsequent operations
6. Balanced consideration of elements of logistics support and operational effectiveness
7. Central model control and responsive adaptation to new systems

The models for which documentation was collected and reviewed during the SCALE project are listed in Appendix A.

The following criteria were applied in the selection of an initial set of models for SCALE integration (Cork, 1975:11):

1. Coverage of logistics elements
2. Special features not duplicated in other models
3. Basis of computation
4. Level of detail

As a result of the model selection criteria the five models proposed for inclusion in the initial SCALE family were (Cork, 1975:17):

1. LSC (AFLC Logistics Support Cost)
2. ORLA (AFLC Optimum Repair Level Analysis)
3. MOD-METRIC (Modified Metric)
4. GEMM (Generalized Electronic Maintenance Model)
5. LOCAM-4 (Logistics Cost Analysis Model-4)

The SAVE Project. The goals and results of the SCALE project provided a foundation for moving on to the development and implementation of SAVE which echoed SCALE's goals. The SAVE research effort was conducted from July through June 1977 by Battelle's Columbus Laboratories and was sponsored by the Air Force Avionics Laboratory (AFAL) located at Wright-Patterson AFB (Cork, 1977).

SAVE is an interactive graphics computer software package which allows analysts to operate a selected set of existing life cycle/logistics support cost models from a common set of data elements. The interactive software transforms the data in a user defined data library into the format required for the model being executed.

The objective of the interactive system is to allow analysts to focus on the synergistic use of the models to analyze a single system and on interpreting the implications of the results rather than on the details of how the input data must be organized and on input data variations between models.

The SAVE Models. Numerous factors influenced the selection of an initial set of models for inclusion in the SAVE system. The major factors affecting model selection were (Cork, 1975:5):

1. Coverage of logistics and technical performance measures.
2. Coverage of the organizational hierarchy of logistics cost analysis issues.

Additional factors considered were extent of past usage and acceptance of the model, model complexity, and valuable unique aspects of the model. The five models currently implemented in SAVE are (Cork, 1975:5):

1. CACE (Cost Analysis Cost Estimating)
2. LSC (AFLC Logistics Support Cost)
3. LCC-2 (Life Cycle Cost-2)
4. GEMM (Generalized Electronics Maintenance Model)
5. MOD-METRIC (Modified Metric)

Brief descriptions of the models included in SAVE with emphasis on the LSC model can be found in Appendix B. For more detailed model descriptions consult the reference found beside each model acronym in Appendix B.

The SAVE Data Structure. There are two types of information to be entered into the SAVE data base by the user in

order to execute the models. The first of these is the structure (hardware configuration) of the system being modeled and the second is the set of data values describing the system.

The process of defining the hardware configuration consists of breaking the system into its component parts and identifying these to the SAVE program. Component parts consist of line replaceable units (LRUs), shop replaceable units (SRUs), and piece parts. An example of this is shown in Figure 1. It can be seen in this diagram, that there are five levels labelled level 0 through 4. Level 0 is referred to as the "highest" level and level 4 as the "lowest" level. By examining the inverted tree structure in Figure 1, it can be seen that the items shown at each level are the components of the parent item at the next higher level. Thus, a GRN-20C TACAN contains a RADIO SET NAVIGATION, a CONTROL MONITOR AN/GRA-111 and an ANTENNA AN/GRA-120, while a RADIO SET NAVIGATION contains a RECEIVER, a CODER-MONITOR, an AMPLIFIER-MODULATOR etc. Each item on the tree is referred to as a node. Thus, at level 0 there is only one node — the GRN-20C node. At level 1 there are three nodes labelled and so on. There is always only one node at level 0, however there may be as many nodes at every other level as the user finds necessary.

The second type of information stored in the data base is the actual data values describing the system being modeled. Since each node of the system structure defines a different "box" in the system, it is evident that data values must be

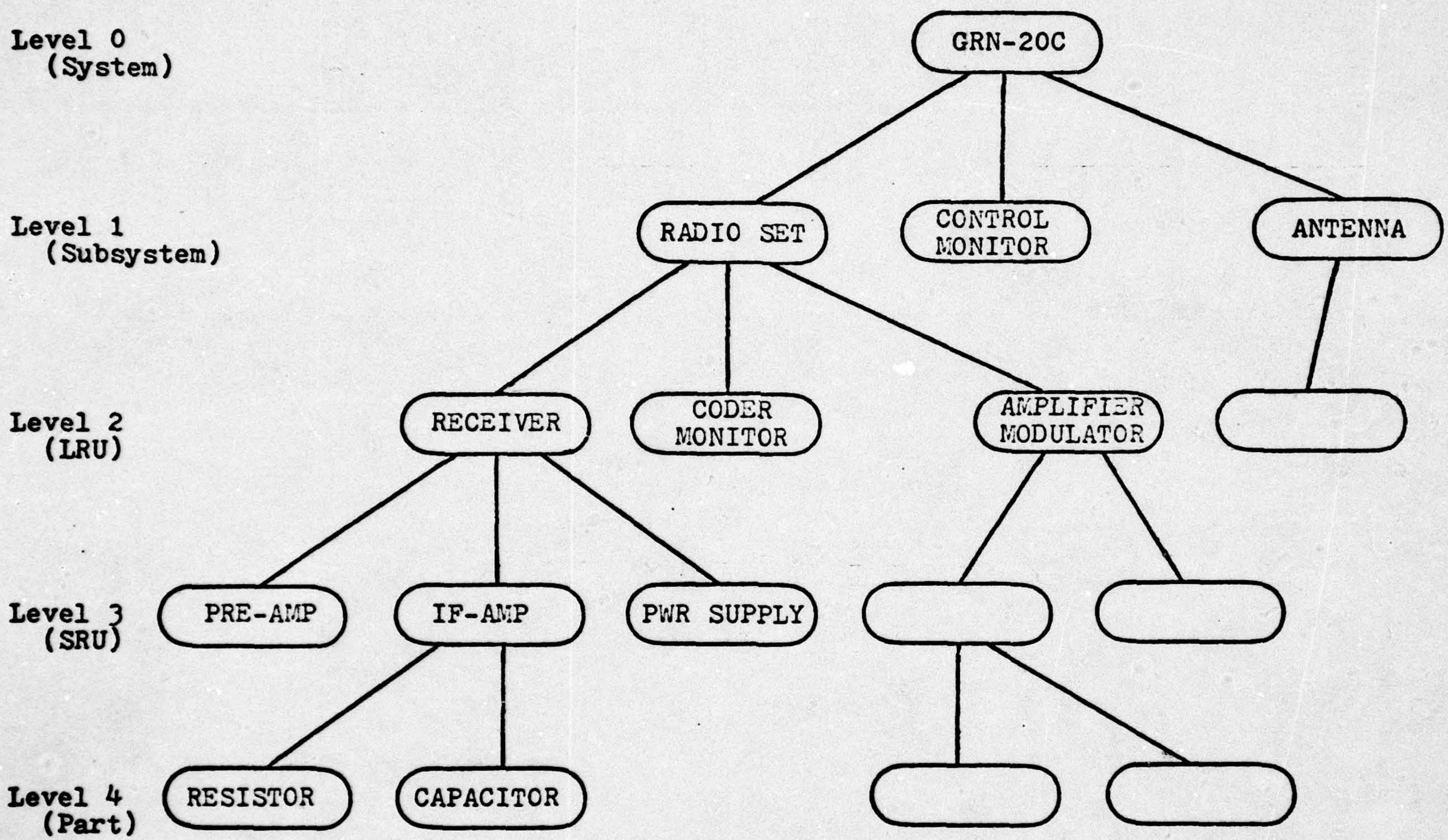

Figure 1. Example of System Structure (Hardware Configuration)

associated with a particular node. In order to facilitate evaluation of alternative proposals (e.g. alternative deployments or alternative contractors' proposals) and the storage of previous analyses, the data base has been designed so that each node may have associated with it more than one set of data values, anyone of which may be used in the execution of a model. Each set of data for a node is referred to as a candidate. Thus, each node in Figure 1 may have one or more candidates. This is graphically shown in Figure 2 where the node at level 1 has one candidate while the node at level 2 has two candidates.

SAVE Execution. The first step required to execute the SAVE computer models is the definition of an execution record. That is, the user must select from all the data he has entered in the data base which candidates are to be used to run a model. To create an execution record, the user must add nodes and candidates from the data base to the execution record. The execution record itself is in the same general format as the data bese (i.e. an inverted tree structure of nodes with associated candidates) although, in general, an execution record will be a subset of the whole data file. Further, when a node is included in the execution record only one of the candidates defined for that node may be added to the execution record. This process is repeated until an execution record referencing all desired data is created. The second feature of an execution record is the ability to perform iterations varying one to five parameters.

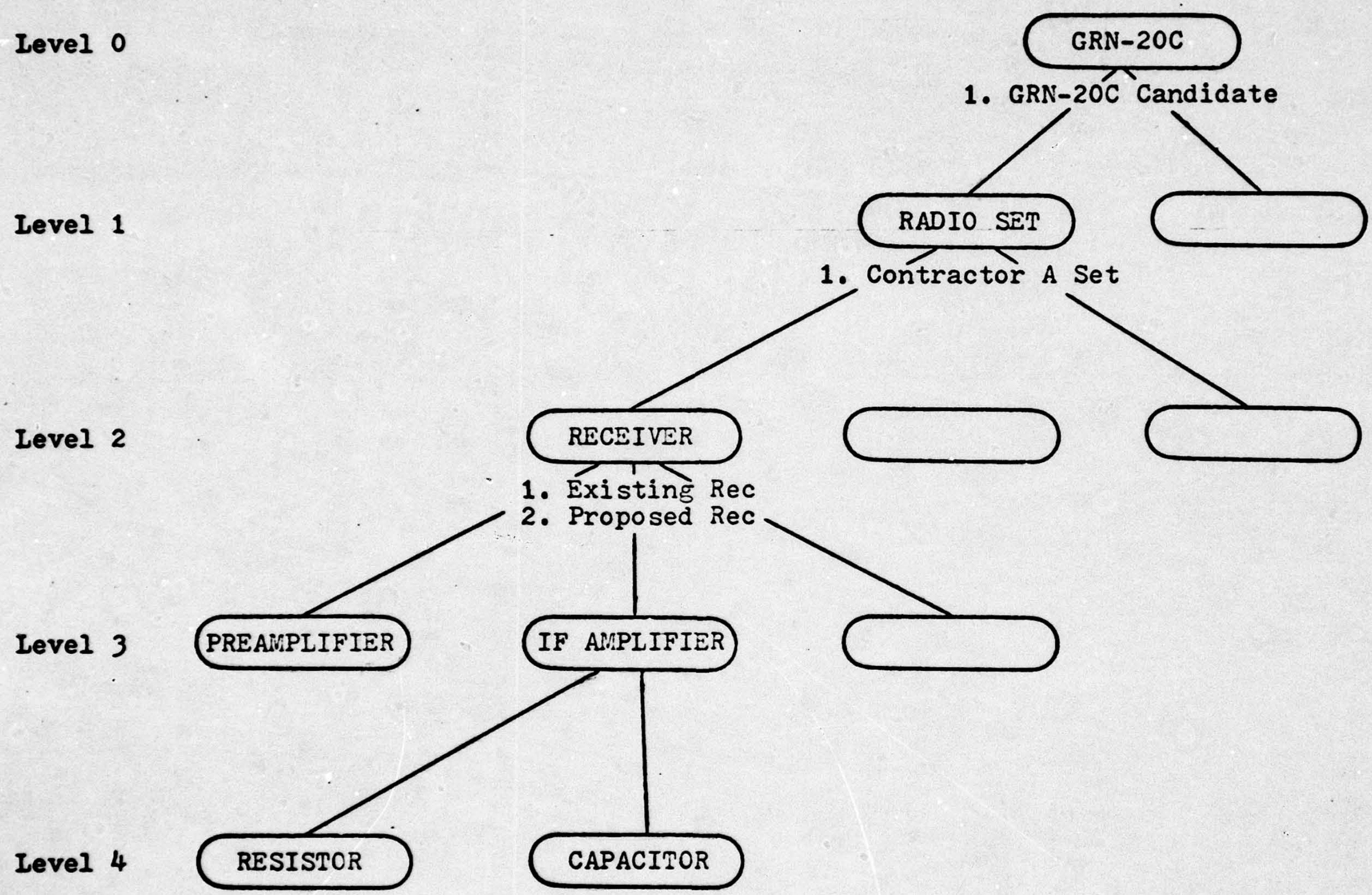

Figure 2. System Structure and Candidates

Once the execution record is defined, the user may execute a model by issuing the RUN command. When the RUN command is entered, the program gets the selected data from the data base and checks it for errors. If no errors are found the necessary control cards and input data are written to a file and for the LSC model, the file is routed to the batch input queue. The LSC model runs as a batch job. Since the results of the model execution are placed in the user's data file, the model cannot run until the user releases control of his data file by exiting the program. When the model completes execution, the user can again enter the program and selectively examine the results as described in the next section of output formats.

SAVE Output Formats. The Executive Command OUT enables the user to examine output from execution of the models. There are two types of on-line output available: 1) All models except MOD-METRIC produce the standard output which is the life cycle costs broken down into ten cost categories and 2) Models LSC, LCC-2 and MOD-METRIC produce optional output which is unique to each model. LSC produces life cycle cost by subsystem, LCC-2 produces a manpower-requirements-by-year-table and MOD-METRIC produces a table of backorders versus budget.

The standard output may be displayed in tabular form or in pie chart form. In addition, if iterations were performed any of the standard cost categories may be plotted against the iteration step number.

All optional output may be displayed in tabular form. In addition, the LSC optional output may be displayed in pie chart form and the MOD-METRIC optional output may be plotted.

In the off-line print mode, the entire output of all models or any specific model is available. This off-line output is considerably more detailed and in depth, and reflects the original, independent use of each model.

PRICE Models

PRICE, an acronym for Programmed Review of Information for Costing and Evaluation, is an RCA built system of computer models which allows cost estimates for many systems to be made early in the conceptual design phase of the systems life. This system of models also allows design engineers to evaluate expected cost changes caused by varying such items as reliability, design parameters, performance parameters, cost escalation and others. PRICE was not developed and is not intended to replace conventional detailed cost estimating techniques, instead, it was developed to evaluate concepts (PRICE Maunal, 1977:1.1).

Generally, the input data items required for PRICE are physical characteristics of the design concept under consideration. These physical characteristics include size, weight, type of components (tubes, semi-conductors, ic's), power dissipation, construction type, number of prototypes and production quantity. The level of detail required for these input quantities is no greater than would be required for any other valid estimate of a systems engineering and production costs (PRICE Manual, 1977:1.3).

All PRICE runs are performed on system boxes which are defined by the PRICE user. These PRICE boxes could represent a module, subsystem or even a system depending upon the individual users requirements. When the user has defined the PRICE box as some subcomponent of a system rather than the system itself there is a stack mode available which allows the user to simulate the entire system and stack the boxes as required in order to build the envisioned system. When using this mode, costs are generated for all PRICE boxes as well as expected integration and test costs for the building of the system from the component boxes.

In describing new products and equipment PRICE arbitrarily divides the products into two parts — mechanical and electronic, each with their own set of algorithms (PRICE Manual, 1977:1.6). This division of a product into meaningful electronic or mechanical parts is not easy since a complete system is usually a heterogeneous mixture of numerous different mechanical and electronic assemblies (PRICE Manual, 1977:1.6). RCA seems to feel, however, that the model does a good job in dividing the system and indicates that over time PRICE has been used for evaluations that range through the gamut of equipment complexity from simple, individual digital modules to such complex systems as the Airborne Warning and Control System (AWACS).

In computing costs, PRICE relates physical rather than performance characteristics to cost. The computations are accomplished using physical descriptors due to the large

number of ways available to meet a given performance requirement. For instance, in the TACAN sets under study here, rather than using the parallel system currently in use, the manufacturer could possibly have used much more reliable components and still have met the performance goal. Different approcahes can meet the same performance goal but meeting the same performance goal at the same cost level by both approaches is almost impossible. PRICE uses physical characteristics rather than performance characteristics in cost development. This use of physical descriptors, though, has required that PRICE also have algorithms available to estimate physical characteristics for situations where the weight and size of components is not known. This requirement is not by several methods including computing unknown values from known values and estimating such input items as number of circuits and type of components (PRICE Manual, 1977:1.9).

The credibility of PRICE predictions can be tested by comparing the output with costs experienced with a completed system. This can be accomplished by entering a base year, such as 1960, into the model which then causes PRICE to update its technological status and economics to that year. PRICE will then accept all further inputs for that run in terms of the given base year. By inputing the concepts used in the original design and production phases, PRICE will calculate costs which can be compared to the experienced costs (PRICE Manual, 1977:1.10).

PRICE. The two PRICE models being investigated by this

effort are the basic PRICE model and the PRICE L2 model. The basic PRICE model can be utilized either as a stand alone model or as an input generator for PRICE L. When utilized by itself PRICE can be used to investigate the expected results from varying design factors. In accomplishing this task PRICE uses the physical characteristics of the proposed system as input items. Some of the physical characteristics required are actual physical descriptors of the proposed system such as weight, volume, quantity produced, volume filled with electronics and others. Other of the physical characteristics required as input items have been empirically devised by RCA as a reflection of the typical construction practices for a given item. For instance, a radio receiver to be used in an outer space type application would have a much greater manufacturing complexity of electronics than would a radio receiver used in a fixed ground application and consequently the space receiver would logically be expected to cost more. PRICE ensures that this is taken into account in two ways both by allowing the designer to describe from the RCA empirical data set the manufacturing complexity of both structure and electronics and by allowing the designer to describe how the equipment will be used. This allows the designer to describe how equipment will be deployed even if the envisioned deployment is not the one for which the equipment was originally designed.

The output generated by the PRICE hardware model provides the interested user with expected values for engineering

development and production costs including drafting, design, systems, project management and data costs. Also provided are similar cost figures for manufacturing development and production. Included in the manufacturing cost figures are production costs, prototype costs and expected costs for tooling and test equipment. In addition to the specific expected costs for both engineering and manufacturing, PRICE provides cost ranges which could be logically expected for the engineering and manufacturing of the box. PRICE will, at user command, compute these cost figures for each box originally described by the user, also for the required integration of the individual boxes into a system and finally compile all the engineering and manufacturing costs for the system.

Additionally, PRICE can be and often is used to generate a life cycle cost input file for the PRICE L model. Typically PRICE would only be used to generate an input file for PRICE L if not all the input variable values are known for the system being studied. In this case, although a great deal of information was known about the TACAN systems some of the required values were not known so PRICE was used to generate the PRICE L input file. This allows the PRICE user to use available preliminary design data to predict, through the use of PRICE L, the life cycle cost implications of a proposed equipment design change.

PRICE L. The PRICE Life Cycle Cost model uses the input data provided by the basic PRICE model to predict design, production and support costs. The information required as input

for the model is minimal and can be described by three general categories of data:

1. Deployment and Employment of the system,
2. Physical system descriptors, and
3. Program constants (PRICE constants).

In a typical study, the analyst can generate support costs using one of two primary ways. First, the analyst can allow the program to select the lowest cost maintenance concept from the 28 standard maintenance concepts analyzed by PRICE L. In this mode, PRICE L selects the lowest cost maintenance concept and also provides a chart depicting the percentage of the lowest maintenance cost that the other maintenance concepts could be expected to reach. Secondly, an analyst could generate support cost figures by specifying which standard maintenance concept or combination of standard maintenance concepts will be used in the analysis. This method of generating costs would be most useful in a validation study where a specific maintenance concept was being employed or when studying modification of an existing system where although the LRUs were being modified, the maintenance concept is well established.

In any LCC run the analyst can change parameters, maintenance concepts or any other program constants that require change on an LRU by LRU basis. This interactive capability is easy to use and allows the analyst to accurately depict the manner in which the system being studied is actually supported or expected to be supported. The interactive capability also allows the user to perform an almost instantaneous

sensitivity analysis with a minimun of input parameter changes.

One of the other principal categories of input data is the deployment/employment data. The current PRICE L model, PRICE L2, allows the user to define up to three theaters of operation for each system with system deployment numbers varying by year if required. The deployment/employment data inputs also allow the analyst to describe how and where spare parts are handled, the number of intermediate and depot level maintenance activities and the fraction of the time the equipment will be operated.

Although PRICE L2 does compute support costs there are several categories of support costs that could be important in considering a military systems LCC that are not computed. These cost categories include training, field installation and test, site preparation and maintenance, operations, software and energy. If these costs are known or can be estimated by the analyst, they can be added to the total cost using a cost thruput command, When this command is used no analysis is done on the thruput data, the values are simply added to the total cost computed by PRICE L.

In summary, the PRICE system of models is easy to use and requires a minimum of complex user inputs. The system is operated on a time sharing basis on the users own terminal equipment, allowing for responsive turn around time for studies. Almost all inputs required for a PRICE LCC analysis can be computed using the basic PRICE model. If detailed parameters are known about the system, the initial step of

computing hardware parameters with PRICE can be deleted or the PRICE calculated values can be checked to verify their validity prior to using them for PRICE L inputs. These items and the easily understood output have greatly enhanced the overall user appeal for the PRICE system (Kaufmann, 1978:4).

IV Methodology

The purpose of this chapter is to present specific tasks that were required for evaluation of the LSC and PRICE L2 models. In general, we first assessed the models regarding availability of input data, validity, and sensitivity. The working level knowledge gained from this in depth analysis provided us with data inputs as we moved on to study the models completeness and documentation.

System Description

Basically, a TACAN system consists of an external antenna and a building which houses electronic components. The electronic components are housed in 6 - 8 electrical equipment cabinets depending on the type of TACAN. Each electrical equipment cabinet with its associated electronic components can be easily pictured as an oversized filing cabinet. The electronic components are contained within drawers which slide in and out of their respective equipment cabinet. These drawers were defined to be LRUs for the purposes of this thesis effort. Figure 3 shows a generalized block diagram of a TACAN system. As can be seen from the block diagram a TACAN system typically consists of a single antenna subsystem, a single control group, two receiver/transmitter groups and two power supply groups. At any one time only one receiver/transmitter group and one power supply group are operational while the duplicate groups are in a standby mode. The failure of a component in the operational units will

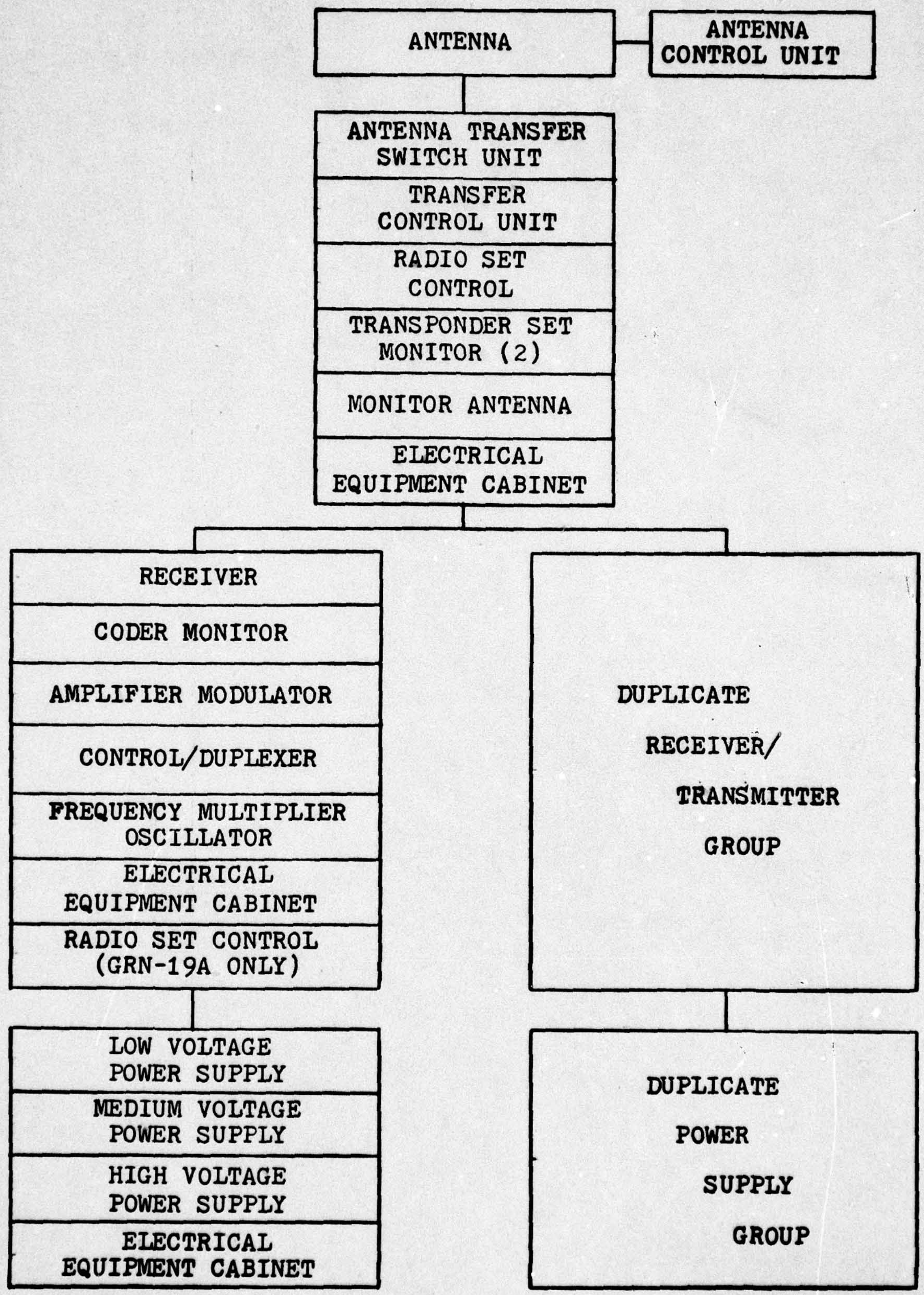

Fig 3. TACAN LRU Breakdown

cause the control group to switch over to the standby groups in order to keep the system operational. In this was the system fault can be repaired by the maintenancs man and yet the system will remain operational. Typically, the failure of a given LRU (drawer) is corrected by sliding out the drawer (thereby exposing lower indentured electronic modules and piece parts), isolating the fault and repairing the failed component on the equipment. Approximately 96 percent of the corrective maintenance performed on any given LRU is accomplished in this manner. A failed LRU that is unable to be repaired on the equipment would be taken to a base shop facility and subsequently shipped to a central depot for repair. While navigational aids maintenance technicians do attempt to repair removed LRUs and other electronic components prior to returning them to the depot maintenance facility, we have assumed in this report that all drawers (LRUs) removed from the equipment are in fact shipped to the central depot for repair (NRTS = 1.0 and RTS = 0.0).

In addition to corrective maintenance, scheduled preventative maintenance is also accomplished on TACAN systems. Preventative maintenance is accomplished at specified intervals (7, 14, 28, 56, 84, 168 days) and each maintenance action generally takes a predetermined amount of time.

As in most maintenance environments, support equipment is required for both corrective and preventative maintenance actions. The support equipment required for TACAN systems maintenance is primarily general in nature (e.g. multimeters

and oscilliscopes) and not specifically required for only one piece of equipment. Consequently, all support equipment is referred to as common support equipment.

System/LRU Identification

Since both the LSC and PRICE L2 models are set up to consider LRUs/FLUs, SRUs, and finally piece parts, initial efforts in developing a methodology to use these cost models in the CEM environment was directed toward an understanding of the specific TACAN systems addressed by this study to fit these TACAN systems to the structure required by the cost models. It was first necessary to identify the system LRUs from the various subsystems, components, and modules that make up a TACAN system. After many hours of discussion with AFCS maintenance experts from Scott AFB and Wright-Patterson AFB, and numerous on-site inspections of the TACAN systems, a system breakdown into subsystems and LRUs was arrived at consistent with maintenance practice and the structure required by the cost models. The following three subsystems and their associated Work Unit Code (WUC) were identified for each TACAN system:

1. RADIO SET NAVIGATION — (AA000)
2. CONTROL MONITOR AN/GRA-111 — (AB000)
3. AN/GRA-120 ANTENNA GROUP — (AC000)

Table I shows an example of the WUC structure for the Radio Set Navigation Subsystem. The complete WUC structure for each TACAN system can be found in T.O. 31R-1-06-1. The final breakdowns from the support WUC structure to the system

TABLE I

AN/GRN-19A Radio Set Navigation Work Unit Codes

T.O. 31R-1-06-1

AN/GRN-19A RADIO SET

WORK UNIT CODE	
AA000	RADIO SET NAVIGATION
AAA00	RECEIVER-TRANSMITTER GROUP OZ-12A
AAAA0	RECEIVER R-1657A
AAAAA	MIXER PREAMPLIFIER
AAAAB	IF AMPLIFIER
AAAAC	VIDEO AMPLIFIER
AAAAD	POWER SUPPLY
AAAAE	SQUITTER CONTROL
AAAB0	CODER-MONITOR KY-682
AAABA	VIDEO CHASSIS
AAABB	POWER SUPPLY
AAABC	KEYER SUBASSY
AAABD	DELAY LINE
AAABE	IDENTITY TONE SUBASSY
AAABF	MAGNETIC VARIATION SUBASSY
AAAC0	AMPLIFIER-MODULATOR AM-1701A
AAACA	BIAS POWER SUPPLY
AAACB	KLYSTRON COMPARTMENT
AAAD0	DUPLEXER CU-787
AAADA	RECEIVER PRESELECTOR
AAADB	RF FILTER, LOW BAND
AAADC	RF FILTER, HIGH BAND
AAADD	RF FILTER, UNIVERSAL
AAAE0	FREQUENCY MULTIPLIER-OSCILLATOR CV-2697
AAAEA	LOW BAND RF CHASSIS
AAAEB	HIGH BAND RF CHASSIS
AAAEC	VIDEO CHASSIS
AAAED	BLANKING PULSE ASSY
AAAF0	ELECTRICAL EQUIPMENT CABINET CY-6805
AAAFA	BLOWER COMPARTMENT
AAAG0	RADIO SET CONTROL C-8419
AAA99	NOC*

TABLE I (Continued)

WORK UNIT CODE	
AABOO	POWER SUPPLY GROUP OP-57
AABAO	LOW VOLT POWER SUPPLY PP-6406
AABBO	MEDIUM VOLT POWER SUPPLY PP-2502
AABCO	HIGH VOLT POWER SUPPLY PP-2503
AABDO	ELECTRICAL EQUIPMENT CABINET CY-6806
AABDA	BLOWER ASSY
AAB99	NOC*

* Not Otherwise Coded

LRU structure for each of the three TACAN systems are shown in Tables II, III, and IV.

Model Data Requirements

Following the determination of the required LRU structure we next focused our attention on model data requirements. The distribution of LSC data items by the sections, subsections, and levels defined in SAVE are shown in Table V. The specific data item requirements of the LSC model executed via the SAVE computer software are listed in Appendix C. As is apparent from the table, specific data is required at level 0 (system level), level 1 (subsystem level), and level 2 (LRU level).

For completeness and to assist in cross referencing from the SAVE to LSC documentation, the LSC model data items are included in Appendix D (LSC Model User's Handbook, 1976: Apendix 2).

PRICE Data Inputs

The specific data items required to run the PRICE models used in this study are shown in Table VI. For this study two PRICE models were used, PRICE and PRICE L2. PRICE was used to generate a PRICE L2 input file in order to estimate values for unknown variables. In this way all that was required to run PRICE L2 was to correct critical input values (e.g. MTBF and MTTR) to allow the model to accurately represent the TACAN system being modeled. As can be seen from the table the input values required for PRICE are physical parameters

TABLE II

WUC to LRU Structure AN/GRN-19A

SYSTEM - AN/GRN-19A

SUBSYSTEM 1 - (AA000) Radio Set Navigation

LRUs - (AAAA0) Receiver R-1657A

(AAAB0) Coder-Monitor KY-682

(AAAC0) Amplifier-Modulator AM-1701A

(AAAD0) Duplexer CU-787

(AAAE0) Frequency Multiplier-Oscillator CV-2697

(AAAF0) Electrical Equipment Cabinet CY-6805

(AAAG0) Radio Set Control C-8419

(AABA0) Low Voltage Power Supply PP-6406

(AABB0) Medium Volt Power Supply PP-2502

(AABC0) High Volt Power Supply PP-2503

(AABD0) Electrical Equipment Cabinet CY-6806

SUBSYSTEM 2 - (AB000) Control Monitor AN/GRA-111

LRUs - (ABA00) Antenna Transf Sw Unit SA-1649

(ABE00) Transfer Control Unit C-8424

(ABF00) Radio Set Control C-2234

(ABG00) Transponder Set Monitor ID-1657

(ABH00) Electrical Equipment Cabinet MT-4155

(ABJ00) AT-592 Monitor Antenna

SUBSYSTEM 3 - (AC000) AN/GRA-120 Antenna Group (High Band)

LRUs - (ACA00) AS-2557/G Antenna Assy

(ACB00) C-8580 Control

TABLE III

WUC to LRU Structure AN/GRN-20B

SYSTEM - AN/GRN-20B

SUBSYSTEM 1 - (AA000) Radio Set Navigation

LRUs - (AAAA0) Receiver R-1659

(AAAB0) Coder-Monitor KY-685

(AAAC0) Amplifier-Modulator AM-1872

(AAAD0) Control Duplexer C-8422

(AAAE0) Frequency Multiplier-Oscillator CV-650

(AAAF0) Electrical Equipment Cabinet CY-6211

(AABA0) Low Volt Power Supply PP-6409

(AABB0) Medium Volt Power Supply PP-1928

(AABC0) High Volt Power Supply PP-1927

(AABD0) Electrical Equipment Cabinet CY-6812

SUBSYSTEM 2 - (AB000) Control Monitor AN/GRA-111

LRUs - (ABA00) Antenna Transf Sw Unit SA-1649

(ABE00) Transfer Control Unit C-8424

(ABF00) Radio Set Control C-2234

(ABG00) Transponder Set Monitor ID-1657

(ABH00) Electrical Equipment Cabinet MT-4155

(ABJ00) AT-592 Monitor Antenna

SUBSYSTEM 3 - (AC000) AN/GRA-120 Antenna Group (High Band)

LRUs - (ACA00) AS-2557/G Antenna Assy

(ACB00) C-8580 Control

TABLE IV

WUC to LRU Structure AN/GRN-20C

SYSTEM - AN/GRN-20C

SUBSYSTEM 1 - (AA000) Radio Set Navigation

LRUs - (AAAA0) Receiver R-1659A

(AAAB0) Coder-Monitor KY-685A

(AAAC0) Amplifier-Modulator AM-1915

(AAAD0) Control-Duplexer C-8423

(AAAE0) Frequency Multiplier-Oscillator CV-673

(AAAF0) Electrical Equipment Cabinet CY-6813

(AABA0) Low Volt Power Supply PP-6624

(AABB0) Medium Volt Power Supply PP-1928A

(AABC0) High Volt Power Supply PP-2044

(AABD0) Electrical Equipment Cabinet CY-6814

SUBSYSTEM 2 - (AB000) Control Monitor AN/GRA-111

LRUs - (ABA00) Antenna Transf Sw Unit SA-1649

(ABE00) Transfer Control Unit C-8424

(ABF00) Radio Set Control C-2234

(ABG00) Transponder Set Monitor ID-1657

(ABH00) Electrical Equipment Cabinet MT-4155

(ABJ00) AT-592 Monitor Antenna

SUBSYSTEM 3 - (AC000) AN/GRA-120 Antenna Group (High Band)

LRUs - (ACA00) AS-2557/G Antenna Assy

(ACB00) C-8580 Control

TABLE V

SAVE Data Items (LSC)

DISTRIBUTION OF LSC DATA ITEMS BY SECTIONS, SUBSECTIONS AND LEVELS

SECTION	SUBSECTION	Library Level 0	1	2
1	WEAPON SYSTEM DEPLOYMENT, USAGE AND CHARACTERISTICS			
	1 WEAPON SYSTEM DEPLOYMENT	5	1	
	2 MISSION UTILIZATION	2		1
	3 EQUIPMENT CHARACTERISTICS	2	3	3
2	MAINTENANCE RATES, ACTIVITIES AND COSTS			
	1 RELIABILITY AND MAINTENANCE RATE FACTORS		3	3
	2 LEVEL OF REPAIR		1	3
	3 CORRECTIVE ACTION ACTIVITIES AND COSTS	2	3	8
	4 SCHEDULED MAINTENANCE ACTIONS AND COSTS		2	
3	PERSONNEL-OPERATIONS, MAINTENANCE AND TRAINING			
	1 PERSONNEL REQUIREMENTS	4	2	
	2 PERSONNEL COSTS		4	
4	SPARES-INITIAL AND REPLENISHMENT			
	1 STOCKAGE OBJECTIVES	1	1	
	2 COMPUTATIONAL TIME FACTORS	2	5	
5	SUPPORT EQUIPMENT AND FACILITIES			
	1 SUPPORT EQUIPMENT USAGE			30
	2 SUPPORT EQUIPMENT COSTS		31	
6	LOGISTICS OPERATIONS			
	1 SUPPLY MANAGEMENT FACTORS	4		3
	2 TRANSPORTATION FACTORS	3		
	3 TECHNICAL ORDERS	1	2	

TABLE VI PRICE Data Items

PRICE Input Data Worksheet

Item ____________ **Date** ____________

General	QTY	PROTOS	WT	VOL	MODE
	QTYSYS	INTEGE	INTEGS	AMULTE (%)	AMULTM (%)
Mechanical/ Structural	WS	MCPLXS	PRODS	NEWST	DESRPS
Electronics	USEVOL	MCPLXE	PRODE	NEWEL	DESRPE
	PWR	CMPNTS	CMPID	PWRFAC	CMPEFF
Engineering	ENMTHS	ENMTHP	ENMTHT	ECMPLX	PRNF
Production	PRMTHS	PRMTHF	LCURVE	ECNE	ECNS
Purchased Item (Mode 3)	WS	BVCOST	LCURVE		
GFE (Mode 4)	WS	MCPLXE	MCPLXS		
Additional Data (Modes 9 & 10)	MCONST	MEXP	WECF	TARCST (Mode 10 only)	
Global	YEAR	ESC	PROJCT	DATA	TLGTST
	PLTFM	SYSTEM	PPROJ	PDATA	PTLGTS

MODES

0 PRINT TOTALS	6 MODIFIED PURCH ITEM
1 E/M ITEM	7 MODIFIED GFE ITEM
2 MECH ITEM	8 PARASYN
3 PURCH ITEM	9 E/M ITEM CALC WT & VOL
4 GFE ITEM	10 GECSYN
5 INTEG & TEST	

Notes:

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TABLE VI (Continued) PRICE Data Items

PRICE L Input Data Worksheet

File name: ____

Sheet ___ of ___

Title:			**Date:**
Mean Time Between Failure MTBF	LRU Mean Time To Repair TF	Module Mean Time To Repair TMO	LRU's per Equipment Location EE
Cost of an LRU In Production CUP	Cost of a Module In Production CMP	Cost of a Part In Production CPP	On-Equipment Repair Part Cost CPPE
Cost of Engineering Development CEND	Non-Recurring Production Costs CPE	Contractor Cost for LRU Repair CUR	Contractor Cost for Module Repair CMR
Number of Module Types P	Number of Part Types PP	Fraction of Non-Standard Parts FNSP	
Cost of LRU Test Set CFIM	Cost of Module Test Set CFIP	Floor Space for LRU Test Set FTSOF	Floor Space for Module Test Set FTSOP
LRU Checkout Time at Organization TC	Cost of LRU Checkout Test Set CCOU	Floor Space for LRU Checkout Test Set FTSOC	
PRICE Improvement Curve for LRU's EUP	PRICE Improvement Curve for Modules EMP	PRICE Improvement Curve for Parts EPP	
Reference Quantity for LRU's RNU	Reference Quantity for Modules RNM	Reference Quantity for Parts RNP	
LRU Weight WU	Module Weight WM	Part Weight WP	
LRU Storage Volume CUBEU	Module Storage Volume CUBEM	Part Storage Volume CUBEP	
Years in Development Phase YD	Years in Production Phase YP		

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TABLE VI (Continued) PRICE Data Items

PRICE L Input Data Worksheet

File name: ____________

Sheet ___ of ___

Title: THRU ________________________________ Date: ____________

DEVELOPMENT ________ PRODUCTION ________ SUPPORT ________ TOTAL ________

Comments: ____

Title: THRU ________________________________ Date: ____________

DEVELOPMENT ________ PRODUCTION ________ SUPPORT ________ TOTAL ________

Comments: ____

Title: THRU ________________________________ Date: ____________

DEVELOPMENT ________ PRODUCTION ________ SUPPORT ________ TOTAL ________

Comments: ____

Title: THRU ________________________________ Date: ____________

DEVELOPMENT ________ PRODUCTION ________ SUPPORT ________ TOTAL ________

Comments: ____

Notes: ____

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TABLE VI (Continued) PRICE Data Items

PRICE LD Input Data Worksheet

Deployment File Name ____________

Price L Deployment File
Short Form

Deployment File Title ______________________________ Date: ____________

Support Period (YR) ____________

Number of Theaters ____________

Short Form (0), or Long Form (1) O

Data for Theater One

Number of Equipment Locations: ED (1) ______

Employment: OTF (1) ______

Number of Maintenance Locations: OD (1) ______ DI (1) ______ DD (1) ______

Number of Supply Locations: EDS (1) ______ ODS (1) ______ DIS (1) ______ DDS (1) ______

Data for Theater Two

Number of Equipment Locations: ED (2) ______

Employment: OTF (2) ______

Number of Maintenance Locations: OD (2) ______ DI (2) ______ DD (2) ______

Number of Supply Locations: EDS (2) ______ ODS (2) ______ DIS (2) ______ DDS (2) ______

Data for Theater Three

Number of Equipment Locations: ED (3) ______

Employment: OTF (3) ______

Number of Maintenance Locations: OD (3) ______ DI (3) ______ DD (3) ______

Number of Supply Locations: EDS (3) ______ ODS (3) ______ DIS (3) ______ DDS (3) ______

Comments: ______________________________

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TABLE VI (Continued) PRICE Data Items

PRICE LD Input Data Worksheet

Deployment File Name ____________

Price L Deployment File
Short Form

Deployment File Title ______________________________ Date: ____________

Support Period (YR) ____________

Number of Theaters ____________

Short Form (0), or Long Form (1) O

Data for Theater One

Number of Equipment Locations: ED (1) ______

Employment: OTF (1) ______

Number of Maintenance Locations: OD (1) ______ DI (1) ______ DD (1) ______

Number of Supply Locations: EDS (1) ______ ODS (1) ______ DIS (1) ______ DDS (1) ______

Data for Theater Two

Number of Equipment Locations: ED (2) ______

Employment: OTF (2) ______

Number of Maintenance Locations: OD (2) ______ DI (2) ______ DD (2) ______

Number of Supply Locations: EDS (2) ______ ODS (2) ______ DIS (2) ______ DDS (2) ______

Data for Theater Three

Number of Equipment Locations: ED (3) ______

Employment: OTF (3) ______

Number of Maintenance Locations: OD (3) ______ DI (3) ______ DD (3) ______

Number of Supply Locations: EDS (3) ______ ODS (3) ______ DIS (3) ______ DDS (3) ______

Comments: ______________________________

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relating to size, weight, quantity, and complexity. Each LRU required input data to allow the model to generate costs associated with integrating the LRUs into a total system.

After studying input requirements for both models it was realized that a more detailed understanding of the technical aspects of the equipment, maintenance concepts, support requirements and operational environment was required to assist in gathering the detailed data required as inputs for the cost models. A deeper understanding of TACAN systems also helped to ensure that the raw data (numbers) used as input values reflected the intended meaning of the model variables.

Data Sources

To satisfy the data requirements for the LSC and PRICE models as previously shown in Tables V and VI, numerous data sources were interrogated. Since maintenance activities play such an important role in any logistics support cost analysis, the initial data gathering effort concentrated on the AFM 66-1, Maintenance Data Collection System (MDCS). Within the MDCS, attention was focused on AFLCR 66-15, Product Performance Data System, and specifically data products that addressed on equipment and off equipment maintenance activities. Data products PCN (product control number) D056B 5006 and PCN D056B 5005 were used to obtain values for such data items as MTBF, MTTR, fraction of inherent failures, fraction of induced failures, and rates for RTS, NRTS and COND.

In order to identify and sepatate failure information from other malfunctions and maintenance actions in the D056B

series reports, specific "how malfunctioned" codes are used in combination with selected "action taken" codes as a part of a computer analysis program at AFLC. An explanation and listing of these type codes follows:

1. Type 1 — How Malfunction Codes — this code indicates that an item no longer can meet the minimum specified performance requirement due to its own internal failure pattern.

2. Type 2 — How Malfunction Codes — this code indicates that an item no longer can meet the minimum specified performance requirement due to some induced condition and not due to its own internal failure pattern.

3. Type 6 — How Malfunction Codes — this code indicates that maintenance resources were expended due to policy, modification, location, or cannibalization and no defect existed at the time of maintenance.

For the purposes of the LSC and PRICE L2 models the failure definition included both Type 1 and 2 How Malfunction Codes. This was explicitly required by the models and makes sense from a maintenance and logistic support point of view. Regardless of whether a failure is caused by an inherent or an induced condition, maintenance must still be performed on the item. Consequently, when computing MTBF for the purposes of the cost models using the formula

$$MTBF = \frac{\text{equipment operating hours}}{\text{number of failures}} \qquad (1)$$

both inherent and induced failures were included in the failure definition.

The D056 failure data analysis served to manually cross check another computer product specially generated by AFCS. In July 1979, a special MDCS data base retrieval was prepared

by HQ AFCS/LGMMA which provided data by WUC for failures, fixes, man hours, clock hours, MTTR, inventory, and MTBF. The data provided by this data product was used as input values for the cost models when dealing with MTBF and MTTR.

While the D056 data system is tied to the WUC structure many other data systems are tied to the federal stock number (FSN) of the end item. This fact became apparent when an attempt to gather LRU specific cost data was initiated. The approach used in gathering the cost data required identifying both a part number and a stock number for each LRU. The part numbers were found by referencing system illustrated parts breakdown and then cross referencing to microfiche products for translation part number to federal stock number and finally to cost. The costs obtained by this method were in 1979 dollars.

Additionally FSNs were required to allow interrogation of the H036B Depot Maintenance Industrial Fund (DMIF) Cost Accounting Production Report which provided summaries of depot overhaul and repair costs per FSN.

Many other data products and specific data values were obtained as a result of direct contact with personnel from HQ AFCS, Scott AFB and 2046 Communications and Installations Group, Wright-Patterson AFB.

An Organizational Item List (TA 665) was provided which listed specific items of support equipment required for TACAN systems. In addition to the Support Equipment (SE) nomenclature, the Organizational Item List listed the FSN of each

piece of SE. Using the FSN to enter data product PCN CB23FODA provided by HQ AFCS, the cost of each piece of SE was identified. The cost of each piece of SE was then prorated to one, two or all three of the subsystems depending on how many of the subsystems the SE was used for during maintenance. The cost proration provided a common cost of SE per subsystem. Note that during this study support equipment costs were identified to the subsystem only and never to specific FLUs/LRUs.

For the PRICE L2 model the costs for common support equipment were not used since PRICE generates its own costs for unique LRU support equipment and does not specifically consider common support equipment.

To help clear up conflicting inventory figures found in the various data systems used, HQ AFCS provided a World Wide Facility Listing — TRACALS-NAVAIDS. The listing indicated the number of TACAN systems by type and location. Inventory figures are extremely important because they drove total operating hours which in turn, combined with the number of failures, drove the MTBF estimate used.

The final data source used in this study consisted of standard values obtained form both AFR 173-10 Volume I, Volume II and AFLCR 173-10. The standard values covered such data elements areas as labor rates, inventory costs, transportation, packaging, shipping costs, and repair-cycle times. In exercising the LSC model, these government furnished standard data values were used without change. The standard

values have been developed from historical cost accounting information and special studies and are updated by responsible AFLC agencies as required (LSC Model User's Handbook, 1979:8).

Specific data values, derived from the data sources discussed, that were used when running the cost models are included in Table VII through Table XIII. Table XIV contains a listing of the LSC model variables that are assigned standard values; the current cost model standard values are also identified in Table XIV.

Model Runs

During and after the data gathering effort, baseline data files were constructed for each of the three TACAN systems to satisfy the specific data formats required by the LSC and PRICE models. Subsequently, the cost models were exercised and the model output per TACAN system was compared to the average Operating and Support cost per TACAN system determined by an independenat AFCS cost study. During the comparison, the differences between the cost categories included in the AFCS study and the cost categories included in the cost models were taken into account. Additionally, the method of computing cost within similar cost categories was also taken into account.

Beyond the cost comparisons, sensitivity analysis was performed on key model variables to determine the percentage change in logistic support cost due to a specific percentage chance in the baseline values of model variables. In most

TABLE VII

Support Equipment Data

Nomenclature	Purchase Cost	Utilization Radio Set	GRA-111	GRA-120
Multimeter Elect Type	$ 232	X	X	X
Frequency Converter	982	X	X	X
Calibrator	950		X	
Power Meter	784		X	
Wattmeter	815	X	X	
Voltmeter Elec	525	X	X	X
Voltmeter Differential	1,032		X	
Multimeter	92	X	X	X
Test Set-Electron Tube	325	X		
Bolometer	108		X	
Oscilloscope	1,036	X	X	X
Electronic Counter	6,861	X	X	X
Generator-Sweep Model	2,534	X		

(Fiscal Year 1979 Dollars)

TABLE VIII

Worldwide Facility Listing Data

System	Conus	Overseas	Total
GRN-19A	39	26	65
GRN-20B	26	11	37
GRN-20C	20	3	23

TABLE IX

LRU Weight/Volume Input Data

LRU	GRN-19A***		GRN-20B		GRN-20C	
	Wt*	Vol**	Wt	Vol	Wt	Vol
RECEIVER	96.0	2.177	98.0	2.177	59.0	2.177
CODER MONITOR	136.0	3.094	140.0	3.094	84.0	3.094
AMPLIFIER MODULATOR	295.0	6.708	303.0	6.708	182.0	6.708
CONTROL/DUPLEXER	155/125	3.514/5.2	152.0	3.354	91.0	3.354
FREQUENCY MULTIPLIER OSCILLATOR	141.0	3.194	130.0	2.875	78.0	2.875
ELECTRICAL EQUIPMENT CABINET	350.0	16.813	350.0	17.352	264.0	17.352
LOW VOLTAGE POWER SUPPLY	81.0	3.000	81.0	3.000	81.0	3.000
MEDIUM VOLTAGE POWER SUPPLY	57.0	2.111	57.0	2.111	57.0	2.111
HIGH VOLTAGE POWER SUPPLY	104.0	3.833	104.0	3.833	104.0	3.833
ELECTRICAL EQUIPMENT CABINET	205.0	17.350	205.0	17.350	205.0	17.350

TABLE IX (Continued)

LRU Weight/Volume Input Data

LRU	GRN-19A***		GRN-20B		GRN-20C	
	Wt*	Vol**	Wt	Vol	Wt	Vol
TRANSFER CONTROL UNIT	58.0	2.140	58.0	2.140	58.0	2.140
ANTENNA TRANSFER SWITCH UNIT	58.0	2.110	58.0	2.110	58.0	2.110
RADIO SET CONTROL	42.0	3.617	42.0	3.617	42.0	3.617
TRANSPONDER SET MONITOR	102.5	3.240	102.5	3.240	102.5	3.140
MONITOR ANTENNA	2.0	0.052	2.0	0.052	2.0	0.052
ELECTRICAL EQUIPMENT CABINET	296.5	17.350	296.5	17.350	296.5	17.350
ANTENNA	825.0	5.060	825.0	5.060	825.0	5.060
ANTENNA CONTROL UNIT	250.0	15.620	250.0	15.620	250.0	15.620

* All weights are shown in pounds.
** All volumes are shown in cubic feet.
*** GRN-19A has a separate CONTROL and DUPLEXER. GRN 20 Series TACANS have a combined CONTROL DUPLEXER

TABLE X

GRN-19A MTBF/MTTR Input Data

LRU	MTBF (Hrs)	MTTR (Hrs)	Failure Fraction* Inherent	Induced
RECEIVER	3,635	2.96	.650	.300
CODER MONITOR	4,567	3.36	.460	.490
AMPLIFIER MODULATOR	8,482	4.00	.410	.550
DUPLEXER	4,771	1.65	.848	.135
FREQUENCY MULTIPLIER OSCILLATOR	2,796	2.27	.630	.350
ELECTRICAL EQUIPMENT CABINET	29,687	3.38	.100	.760
RADIO SET CONTROL	3,660	1.95	.330	.620
LOW VOLTAGE POWER SUPPLY	7,031	1.59	.170	.800
MEDIUM VOLTAGE POWER SUPPLY	2,451	0.99	.140	.840
HIGH VOLTAGE POWER SUPPLY	3,790	2.16	.220	.760
ELECTRICAL EQUIPMENT CABINET	14,843	3.59	.040	.900
ANTENNA TRANSFER SWITCH UNIT	34,360	2.37	.290	.650
TRANSFER CONTROL UNIT	3,872	2.25	.620	.280
RADIO SET CONTROL	6,517	3.57	.420	.470
TRANSPONDER SET MONITOR	7,422	3.03	.770	.140
MONITOR ANTENNA	33,590	3.58	.290	.430

TABLE X (Continued)

GRN-19A MTBF/MTTR Input Data

LRU	MTBF (Hrs)	MTTR (Hrs)	Failure Fraction* Inherent	Induced
ELECTRICAL EQUIPMENT CABINET	106,872	1.48	.290	.630
ANTENNA	33,590	3.15	.560	.130
ANTENNA CONTROL UNIT	35,624	1.03	.630	.130

* Failure Fractions for Inherent and Induced failures do not add up to one due to D056 data showing no fault found during corrective maintenance.

TABLE XI

GRN-20B MTBF/MTTR Input Data

LRU	MTBF (Hrs)	MTTR (Hrs)	Failure Fraction* Inherent	Induced
RECEIVER	7,472	2.83	.60	.36
CODER MONITOR	6,866	3.48	.53	.42
AMPLIFER MODULATOR	7,698	3.26	.40	.57
CONTROL DUPLEXER	12,702	2.85	.36	.59
FREQUENCY MULTIPLIER OSCILLATOR	2,954	2.32	.65	.34
ELECTRICAL EQUIPMENT CABINET	42,340	2.13	.11	.83
LOW VOLTAGE POWER SUPPLY	9,073	1.17	.23	.75

TABLE XI (Continued)

GRN-20B MTBF/MTTR Input Data

LRU	MTBF (Hrs)	MTTR (Hrs)	Failure Fraction* Inherent	Induced
MEDIUM VOLTAGE POWER SUPPLY	2,954	1.17	.22	.77
HIGH VOLTAGE POWER SUPPLY	5,645	2.02	.16	.81
ELECTRICAL EQUIPMENT CABINET	28,227	2.42	.15	.66
ANTENNA TRANSFER SWITCH UNIT	42,340	3.46	.50	.36
TRANSFER CONTROL UNIT	2,854	1.89	.68	.14
RADIO SET CONTROL	4,619	2.04	.46	.31
TRANSPONDER SET MONITOR	5,523	2.02	.85	.04
ELECTRICAL EQUIPMENT CABINET	27,020	2.57	.14	.71
MONITOR ANTENNA	36,291	0.99	.58	.23
ANTENNA	27,020	1.76	.26	.32
ANTENNA CONTROL UNIT	31,755	2.48	.84	.10

* Failure Fractions for Inherent and Induced failures do not add up to one due to D056 data showing no fault found during corrective maintenance.

TABLE XII

GRN-20C MTBF/MTTR Input Data

LRU	MTBF (Hrs)	MTTR (Hrs)	Failure Fraction* Inherent	Induced
RECEIVER	3,951	2.37	.57	.35
CODER MONITOR	11,193	3.53	.43	.53
AMPLIFIER MODULATOR	5,926	3.94	.42	.57
CONTROL DUPLEXER	7,196	1.35	.28	.66
FREQUENCY MULTIPLIER OSCILLATOR	2,214	2.34	.61	.38
ELECTRICAL EQUIPMENT CABINET	28,783	1.89	.13	.83
LOW VOLTAGE POWER SUPPLY	5,166	0.86	.23	.77
MEDIUM VOLTAGE POWER SUPPLY	2,077	1.15	.23	.77
HIGH VOLTAGE POWER SUPPLY	4,797	1.99	.30	.65
ELECTRICAL EQUIPMENT CABINET	100,740	2.37	.21	.79
ANTENNA TRANSFER SWITCH UNIT	50,370	3.10	.75	.00
TRANSFER CONTROL UNIT	3,875	1.81	.65	.29
RADIO SET CONTROL	5,597	1.96	.31	.50
TRANSPONDER SET MONITOR	5,037	2.40	.85	.07
ELECTRICAL EQUIPMENT CABINET	67,160	1.06	.00	1.00
MONITOR ANTENNA	101,480	1.17	.50	.00

TABLE XII (Continued)

GRN-20C MTBF/MTTR Input Data

LRU	MTBF (Hrs)	MTTR (Hrs)	Failure Fraction* Inherent	Induced
ANTENNA	101,480	2.98	.67	.00
ANTENNA CONTROL UNIT	100,740	0.54	.83	.00

* Failure Fractions for Inherent and Induced failures do not add up to one due to D056 data showing no fault found during corrective maintenance.

TABLE XIII

LRU Purchase Cost Figures

LRU	GRN-19A	GRN-20B	GRN-20C
RECEIVER	$ 6,729	$ 2,040	$14,000
CODER MONITOR	6,850	2,430	1,926
AMPLIFIER MODULATOR	7,206	4,244	3,846
CONTROL DUPLEXER	3,380/ 16,186	13,302	12,356
FREQUENCY MULTIPLIER OSCILLATOR	5,500	4,182	7,880
ELECTRICAL EQUIPMENT CABINET	3,000	3,315	3,315
LOW VOLTAGE POWER SUPPLY	1,916	1,600	1,540

TABLE XIII (Continued)

LRU Purchase Cost Figures

LRU	GRN-19A	GRN-20B	GRN-20C
MEDIUM VOLTAGE POWER SUPPLY	$ 1,180	$ 1,045	$ 902
HIGH VOLTAGE POWER SUPPLY	1,152	1,151	723
ELECTRICAL EQUIPMENT CABINET	2,532	2,532	2,532
ANTENNA TRANSFER SWITCH UNIT	2,394	2,394	2,394
TRANSFER CONTROL UNIT	18,334	18,334	18,334
RADIO SET CONTROL	2,000	2,000	2,000
TRANSPONDER SET MONITOR	3,942	3,942	3,942
ELECTRICAL EQUIPMENT CABINET	1,000	1,000	1,000
MONITOR ANTENNA	221	221	221
ANTENNA	26,451	26,451	26,451
ANTENNA CONTROL UNIT	7,000	7,000	7,000

Note: Costs are expressed in 1979 dollars.

TABLE XIV

Cost Model Standard Values (S)

and Their Associated Variables

Weapon System Variables

IMC	-	Initial management cost to introduce a new line item of supply (assembly or piece part) into the Air Force inventory. (S = $166.25/item) (AFLCR 173-10)
MRF	-	Average manhours per failure to complete off-equipment maintenance records. (S = 0.24 hours)
MRO	-	Average manhours per failure to complete on-equipment maintenance records. (S = 0.08 hours)
OST	-	Weighted average Order and Shipping Time in months. The elapsed time between the initiation of a request for a serviceable item and its receipt by the requesting activity. For CONUS locations, S = 0.394 months (12 days) input as OSTCON. For overseas locations, S = 0.526 months (16 days) input as OSTOS. (AFLCR 173-10) OST = (OSTCON) (1-OS) + (OSTOS) (OS)
PMB	-	Direct productive manhours per man per year at base level (includes "touch time," transportation time, and setup time). (S = 1728 hours/man/year) (AFLCR 173-10)
PMD	-	Direct productive manhours per man per year at the depot (includes "touch time," transportation time, and setup time). (S = 1728 hours/man/year) (AFLCR 173-10)
PSC	-	Average packing and shipping cost to CONUS locations. (S = $0.72/pound) (AFLCR 173-10)
PSO	-	Average packing and shipping cost to overseas locations. (S = $1.49/pound) (AFLCR 173-10)
RMC	-	Recurring management cost to maintain a line item of supply (assembly or piece part) in the wholesale inventory system. (S = $166.25/item/year) (AFLCR 173-10)
SA	-	Annual base supply line item inventory management cost. (S = $8.39/item) (AFLCR 173-10)
SR	-	Average manhours per failure to complete supply transaction records. (S = 0.25 hours)

TABLE XIV (Continued)

TD - Average cost per original page of technical documentation. The average acquisition cost of one page of the reproducible source document (does not include reproduction costs). (S = $200.07/page) (AFLCR 173-10)

TR - Average manhours per failure to complete transportation transaction forms. (S = 0.16 hours)

TRB - Annual Turnover Rate for base personnel. (S = 0.134)

TRD - Annual Turnover Rate for depot personnel. (S = 0.15)

System Variables

BAA - Available work time per man in the base shop in manhours per month. (S = 168 hours) (AFLCR 173-10)

BLR - Base labor rate, including indirect labor, indirect material and overhead. (S = $15.18/hour) (AFLCR 173-10)

BMR - Base consumable material consumption rate. Includes minor items of supply (nuts, washer, rags, cleaning fluid, etc.) which are consumed during repair of items (S = $2.11/hour) (AFLCR 173-10)

BRCT - Average Base Repair Cycle Time in months. The elapsed time for a RTS item from removal of the failed item until it is returned to base serviceable stock (less time awaiting parts). For FLUs of the "black box" variety (e.g., avionics LRUs), the repair of which normally consists of removal and replacement of "plug-in" components (SRUs), S = 0.13 months (4 days). (For other, nonmodular FLUs, S = 0.20 months 6 days). (AFLCR 173-10)

DAA - Available work time per man at the depot in manhours per month. (S = 168 hours) (AFLCR 173-10)

DLR - Depot labor rate, including other direct costs, overhead and G&A. (S = $26.20/hour) (AFLCR 173-10)

DMR - Same as BMR except refers to depot level maintenance. (S = $7.69/hour) (AFLCR 173-10)

DRCT - Weighted average Depot Repair Cycle Time in months. The elapsed time for a NRTS item from removal of the failed item until it is returned to the depot serviceable stock. This includes the time required for base-to-depot transportation and handling and the shop flow

TABLE XIV (Continued)

time within the specialized repair activity required to repair the item. For CONUS locations, S = 1.73 months (52 days) for organic repair, S = 2.06 months (62 days) for contractual repair, input as DRCTC. For overseas locations, S = 1.90 months (57 days) for organic repair, S = 2.20 months (66 days) for contractual repair, input as DRCTO. (AFLCR 173-10)
DRCT = (DRCTC) (1-OS) + (DRCTO) (OS)

cases, the model variables of interest were applicable at the subsystem or LRU level. Consequently, when investigating the effect of a percentage change in a certain model variable, the same percentage change was made across all subsystems or LRUs as applicable. For instance, when investigating model sensitivity to MTBF (a model variable specific to each LRU), each LRU MTBF was decreased by the same percentage amount. Sensitivity analysis was performed on the following model variables:

1. MTBF (Mean Time Between Failure)
2. MTTR (Mean Time to Repair)
3. RIP (Repair in Place) fraction
4. NRTS (Not Repairable This Station) rate
5. RTS (Reparable This Station) rate
6. COND (Condemnation) rate
7. EBO (Expected Back Order) fraction
8. CAD (Annual Cost to Maintain Parts in Supply System)
9. ANPR (Average Number of Parts Replaced Per Repair)
10. DMH (Depot Mean Time to Repair)

The data gathering, model validation effort, and sensitivity analysis provided a sound foundation on which to assess each model's completeness and documentation. The "hands-on" experience with model usage provided information beyond that found by mere inspection of the model cost categories and documentation. Working with the models required an understanding of how costs were developed in each category. As first time users, working with the models required

reading the model decumentation and provided first hand experience with using the available model documentation.

Summary

This chapter discussed the methodology used to evaluate the LSC and PRICE models, using as criteria, availability of input data, validity, sensitivity, completeness, and documentation. Initially it was necessary to identify the system LRUs from the various subsystems, components, and modules that make up a TACAN system. Following LRU identification, the specific model data requirements were identified and data were gathered from various sources as displayed in the Tables. Subsequently, the models were exercised and validation and sensitivity analyses were performed. Based on the experience gained by working with the cost models, each model was assessed regarding completeness and documentation. The following chapter discusses the results of model evaluation based on the five criteria listed above.

V Results

The purpose of this chapter is to describe the results achieved during this cost model evaluation effort. In general, the chapter describes a cost study provided by HQ AFCS giving a representation of the experienced operations and support costs for NAVAID systems. Additionally, we describe the analysis of availability of input data, completeness, sensitivity, validity, and documentation.

The discussion presented in relation to the LSC model reflects the results of the LSC model run via the AFLC Computational Resources for Engineering and Simulation, Training, and Education (CREATE) system. Initial efforts were aimed at evaluating the LSC model via the SAVE interactive graphics computer software. In addition to access to four other cost models, SAVE offers many features not available on the CREATE LSC model. However, numerous software, coding and documentation problems were encountered with SAVE during the LSC model validation and sensitivity analysis efforts. These problems precluded further evaluation of the LSC model via the SAVE interactive program.

AFCS Cost Study

The cost study provided by HQ AFCS listed a sample of the experienced operations and support costs for NAVAIDS systems. In the study no mention was made concerning the base selection criteria other than a statement that the bases were felt to be representative of their major commands. Of the 42

bases sampled in the cost study, 32 were usable for the purposes of this thesis effort. The data for the remaining 10 bases were not used since the bases either had the wrong TACAN installed or had a combination VOR and TACAN installed. AFCS used the best information available in the preparation of their cost study but the study does caution that the costs should be used for planning purposes only (AFCS Cost Study, 1979:1).

The operation and support cost elements included in the cost study and their source/derivation are as follows (AFCS Cost Study, 1979:2-3):

1. Personnel. This category was broken down into direct and indirect personnel costs. The total cost of direct personnel by type of facility was derived by using the total annual cost to the government for the various military grades (Source AFM 177-101, FY 79 rates). Civilian costs were derived from the overall Air Force average civilian rate for civilians at sampled bases in the U.S. (Source AFR 173-10, Vol I, Table 23, FY 79 rates). Costs associated with indirect personnel costs were prorated to each facility based upon the number of direct personnel authorized for that facility.

2. Base Operating Support Costs (BOS). BOS costs were computed for all direct and indirect personnel at each of the sampled bases (Source AFR 173-10). Costs were then prorated to the facility based on

the number of direct personnel at each facility.

3. Miscellaneous Support Costs. Miscellaneous support costs were computed for all personnel (Source AFR 173-10) and then the miscellaneous support costs for the indirect personnel were prorated to the facility.

4. Permanent Change of Station (PCS). PCS costs were computed for the direct military personnel by type of facility at the sampled bases (Source AFR 173-10, Vol I, Table 27A, FY 79 rates).

5. Training Costs. Training Costs were computed for both direct and indirect personnel by type of facility (Source AFR 173-10, Vol I, Table 29). Training costs for indirect personnel were prorated to each facility based upon the number of direct personnel authorized for the facility. This prorated training cost was added to the direct personnel training cost to derive a total training cost for each facility at the sampled bases.

6. Supply Costs. Average annual supply cost factors for the various types of flight facilities equipment were developed from a previous AFCS cost study and inflated accordingly. Included in these cost factors were expendable items consumed in the operation and maintenance of flight facilities equipment and depot repair items due in from maintenance (DIFM).

Average costs per cost category generated by the report

are shown in Table XV. These average cost values were used in the analysis of the models predictive capabilities by adding average experienced costs per cost category to the model predicted LSC for those cost categories not included in the model.

TABLE XV

Average Values for Cost Study Categories

Category	GRN-19A	GRN-20B	GRN-20C
DIRECT PERSONNEL	$42,000	$40,657	$29,807
INDIRECT PERSONNEL	14,721	15,657	8,527
SUPPLIES	5,635	4,513	2,659
BOS	9,852	8,150	8,248
MISC	2,486	2,456	1,886
TRAINING	9,940	8,827	7,661
PCS	2,396	2,407	1,160
TOTAL	87,030	82,667	59,948

Availability of Input Data

Input data for the models were gathered by using the data systems described in the previous chapter. The data collected particularly from the D056 data system could be inaccurate due to the way in which data is entered into the system. Items are entered into the data system by the maintenance technician filling out a form describing the action

taken and the time required to perform the maintenance action. Discussions with maintenance personnel (both AFCS and Non-AFCS) have indicated that in some instances the data forms are not accurately completed and may not accurately represent the actual experienced repair times. Although the data may not be totally accurate it is all that is available and was used after as much checking as possible.

Some of the specific data items required for the PRICE model were not readily available in a usable form. For instance, available technical data did not specifically identify individual drawer (LRU) weights and volumes. This data along with construction type was required to estimate production costs for the LRUs and to estimate LRU MTBF and MTTR values. This data requirement was finally satisfied by on site visits to TACAN installations where drawers were physically measured to determine their volume. Weight was then estimated at 28 pounds per cubic foot. The weight per cubic foot value used to estimate the weight of each LRU is the value recommended by the PRICE hardware model as the average weight per cubic foot for the tube type construction. Other PRICE required input data values were either readily available or estimated using PRICE empirical data sets for the individual input parameter.

In comparison to the PRICE L2 model, the LSC model required a list of 95 explicit data elements which form the basis of the mathematical relationships in the model. In the case of new system acquisitions the data elements can be

divided into four categories which identify the nature and origin of the data:

1. Program Elements — operating hours programs, deployments, operating locations
2. Contractor — Furnished System Elements
3. Contractor — Furnished FLU Elements
4. Government — Furnished Standard Elements

During this study involving existing TACAN systems, we had to rely on historical data contained in various data systems. In every case the data was available. However, considerable time and effort were required to identify, access, and interpret the data systems.

In general, input data was fairly available for both models, however, the available data was not always in a usable form. Additionally, possibly due to researcher inexperience, applicable data systems sometimes proved to be elusive and specific information about data systems seemed, in many cases, at best sketchy. Another general data collection problem experienced on several occasions was the inflexivility of the data systems themselves. In at least one instance we were advised that the requested information could possibly be obtained but that it was only available at four or five times during the month. Input data collection proved to be a fairly large stumbling block during this thesis effort.

Validity

As was pointed out in the introduction, a cost analyst

using a cost model must be satisfied that the cost model being used is in fact predicting accurately the costs being considered. A summary of the baseline support costs generated by PRICE L2 are depicted in Table XVI.

TABLE XVI

PRICE L2 Baseline Support Costs

System	PRICE L2 Predicted Support Costs	Experienced Costs
GRN-19A	$27,352	$87,030
GRN-20B	25,230	82,667
GRN-20C	28,048	59,947

As is readily apparent from Table XVI, the support costs predicted by PRICE L2 are significantly lower than the systems experienced support costs. This is not particularly surprising, however, when one considers the cost categories listed in the AFCS cost study versus the cost categories computed by PRICE L2. For instance, the AFCS cost study considers such cost categories as training, base operating support, PCS, indirect personnel and miscellaneous personnel support costs while PRICE L2 does not compute values for these cost categorine. Table XVII shows predicted costs if the values discussed above are considered.

From the table it is readily apparent that the cost

TABLE XVII

PRICE L2 Baseline Support Costs and Adjustments

System	PRICE Predicted Cost	Costs Not Considered	Total	Experienced Costs
GRN-19A	$27,352	$39,395	$66,747	$87,030
GRN-20B	25,230	37,497	62,727	82,667
GRN-20C	28,048	27,482	55,530	59,948

categories not considered do play a significant part in the support costs of the systems being studied. Even more accurate results may be possible if differences in the way in which direct personnel costs were measured were readily measurable. Personnel costs were computed on the basis of manpower authorizations in the AFCS study while PRICE L computed manpower costs only for predicted maintenance manhours. Of particular interest is the cost ranking among the systems. In order of decreasing system cost, the PRICE L2 model ranked the GRN-20C first followed by the GRN-19A and the GRN-20B. Note, that after the cost adjustments the systems assumed the ranking indicated by the AFCS cost study.

A summary of the baseline logistics support costs generated by the LSC model are depicted in Table XVIII.

As with the PRICE L2 model, the costs predicted by the LSC model are significantly lower than the system's experienced support costs. Again the differences are attributable

TABLE XVIII

LSC Baseline Support Costs

System	LSC Predicted Support Cost	Experienced Costs
GRN-19A	$18,353	$87,030
GRN-20B	13,540	82,667
GRN-20C	15,150	59,947

to the facts that the LSC model and the AFCS cost study do not include the same cost categories, and within the same cost categories, costs are computed differently. The LSC model does not compute base operating support costs (BOS), miscellaneous support costs, permanent change of station (PCS) costs and support personnel costs as defined in the AFCS cost study. In addition, the LSC model computes costs within the direct personnel and training cost categories differently. Direct personnel costs are computed based on "workload related personnel equivalents" which are based on direct labor man-hours. Training costs are computed based on the "workload related personnel equivalents" and a personnel turnover rate. Table XIX shows the predicted LSC costs adjusted for all but the direct personnel cost category.

As with the PRICE L2 model, the LSC predicted support costs could be adjusted even further if the direct personnel cost category is considered. The AFCS study computes direct

TABLE XIX

LSC Baseline Support Costs and Adjustments

System	LSC Predicted Cost	Costs Not Considered	Total	Experienced Cost
GRN-19A	$18,353	$39,395	$57,748	$87,030
GRN-20B	13,540	37,497	51,037	82,667
GRN-20C	15,150	27,482	42,632	59,948

personnel costs based on a dedicated manpower basis as described earlier in this chapter. Consequently, the direct personnel cost reflects the manpower authorizations (body count) for the TACAN system. The LSC model only captures a small part of this cost since it deals with "workload related personnel equivalents" instead of the actual number of dedicated personnel required for direct operation and support of the TACAN system.

Sensitivity

After the baseline runs were performed to discern what support costs were being predicted by the different cost models, sensitivity analysis was performed on key parameters. Sensitivity analysis is a useful technique for accomplishing two objectives. First it can evaluate the effect of ambiguity in data. If there are key parameters about which the values are uncertain, the use of several values in a reasonable range will show how sensitive the results are to

variations of the uncertain parameters. It can also be used to identify and investigate those parameters that have a significant influence on the final result.

In performing sensitivity analysis on the PRICE L2 model, the key parameters varied were MTBF, MTTR, average number of parts replaced per repair action, and the cost of maintaining parts in the supply system. Sensitivity analysis for PRICE L2 was limited to the GRN-20B due to other system similarities and to investigate the sensitivity of a system other than the one used in the LSC sensitivity analysis.

In performing sensitivity analysis on the LSC model the key parameters that were varied included MTBF, MTTR, RIP, NRTS, RTS, COND, EBO, and depot MTTR (DMH). In addition, the LSC variables BMC and DMC which capture the average cost per FLU failure for stockage and repair of lower level assemblies at the base and depot respectively, were subjected to sensitivity analysis. In performing the analysis, each variable was varied about its baseline value to determine the effect on the total logistic support cost per system per year. Sensitivity analysis on the LSC model was restricted to the GRN-19A system since it is so similar to the other two TACAN systems under consideration.

Varying MTBF. The MTBF values used in the model baseline runs were derived from an AFCS MDCS data product. While we were relatively confident with the MTBF values, we were interested to see the effect of MTBF on the system support costs. The MTBF values were varied 25% above (1.25 $MTBF_i$)

and 25% below (0.75 $MTBF_i$) the baseline MTBFs ($MTBF_i$) for each LRU. Table XX reflects the LSC results broken out by the ten LSC cost equations. Table XXI reflects the PRICE results broken out by the PRICE cost categories. The costs reflected in each equation or cost category are costs per system per year. As is apparent by inspection of the tables, varying MTBF had little effect on the system support cost. This result is due to the high reliability of the TACAN LRUs.

Varying MTTR. Baseline MTTR values were also derived from the AFCS MDCS data product. The MTTR values were varied 25% above (1.25 $MTTR_i$) and 25% below (0.75 $MTTR_i$) the baseline MTTRs ($MTTR_i$) for each LRU. Tables XXII and XXIII reflect the PRICE results by PRICE cost category and the LSC results by LSC cost equation respectively.

The MTBF and MTTR sensitivity analysis results are shown graphically in Figures 4 and 5 for the LSC and PRICE L2 models respectively. Over the MTBF range shown in the figures, the rate of change of system support cost is increasing as MTBF decreases. In comparison, the rate of change of system support is constant over the MTTR range.

Varying RIP, NRTS, RTS, and COND (LSC model only). The baseline values for RIP (0.96), NRTS (1.0), RTS (0.0), and COND (0.0) were derived from the TACAN maintenance concept and verified via the maintenance data collection system (MDCS). Figure 6 reflects the results on system support cost of varying the four parameters. COND was set to 0.0 and 0.1 while the RIP rate was varied from 0.96 to 0.864 to 0.768.

TABLE XX

ISC Sensitivity Results with Respect to Varying MTBF

ISC Cost Equation (CE)		MTBF (Expressed as a Fraction of Baseline Value)		
		1.25	1.00	0.75
CE1	Cost of FLU Spares	$ 244	$ 253	$ 329
CE2	On-Equipment Maintenance	9,878	10,216	10,780
CE3	Off-Equipment Maintenance	2,182	2,726	3,637
CE4	Inventory Management	212	212	212
CE5	Cost of Support Equipment	3,305	3,305	3,305
CE6	Cost of Personnel Training	669	701	754
CE7	Cost of Management and Technical Data	919	934	960
CE8	Cost of Facilities	0	0	0
CE9	Cost of Fuel Consumption	0	0	0
CE10	Cost of Spare Engines	0	0	0
	TOTAL	17,415	18,353	19,984
% Change in Total Cost		5%	0%	9%
Total Cost Change		938	0	1,631

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TABLE XXI

PRICE Sensitivity Results with Respect to Varying MTBF

Cost Category	MTBF (Expressed as a Fraction of Baseline MTBF)		
	1.25	1.00	0.75
SUPPORT EQUIPMENT	$ 0	$ 0	$ 0
SUPPLY	1,941	2,301	3,147
SUPPLY ADMIN	21,770	21,770	21,771
MANPOWER	859	989	1,206
OTHER	135	170	228
TOTAL	24,704	25,230	26,353

TABLE XXII

PRICE Sensitivity Results with Respect to Varying MTTR

Cost Category	MTTR (Expressed as a Fraction of Baseline MTTR)		
	1.25	1.00	0.75
SUPPORT EQUIPMENT	$ 0	$ 0	$ 0
SUPPLY	2,301	2,301	2,301
SUPPLY ADMIN	21,770	21,770	21,770
MANPOWER	1,050	989	928
OTHER	170	170	170
TOTAL	25,291	25,230	25,169

TABLE XXIII

LSC Sensitivity Results with Respect to Varying MTTR

LSC Cost Equation (CE)	MTTR (Expressed as a Fraction of Baseline Value)		
	1.25	1.00	0.75
CE1 Cost of FLU Spares	$ 253	$ 253	$ 253
CE2 On-Equipment Maintenance	10,614	10,216	9,818
CE3 Off-Equipment Maintenance	2,726	2,726	2,726
CE4 Inventory Management	212	212	212
CE5 Cost of Support Equipment	3,305	3,305	3,305
CE6 Cost of personnel Training	726	701	676
CE7 Cost of Management and Technical Data	934	934	934
CE8 Cost of Facilities	0	0	0
CE9 Cost of Fuel Consumption	0	0	0
CE10 Cost of Spare Engines	0	0	0
TOTAL	18,769	18,353	17,923
% Change in Total Cost	2.3%	0%	2.3%
Total Cost Change	416	0	430

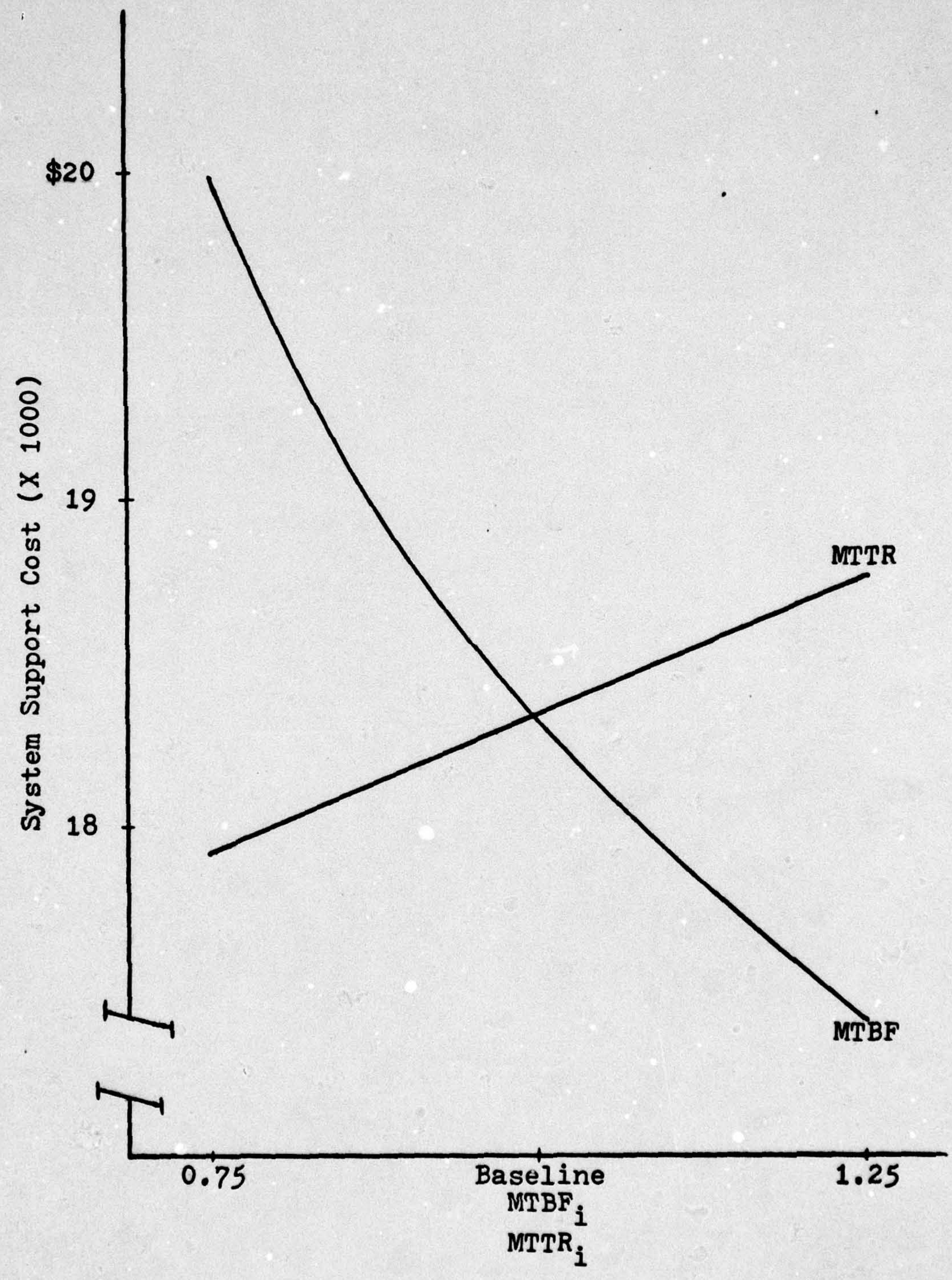

Figure 4. LSC Sensitivity Results with Respect to Varying MTBF/MTTR

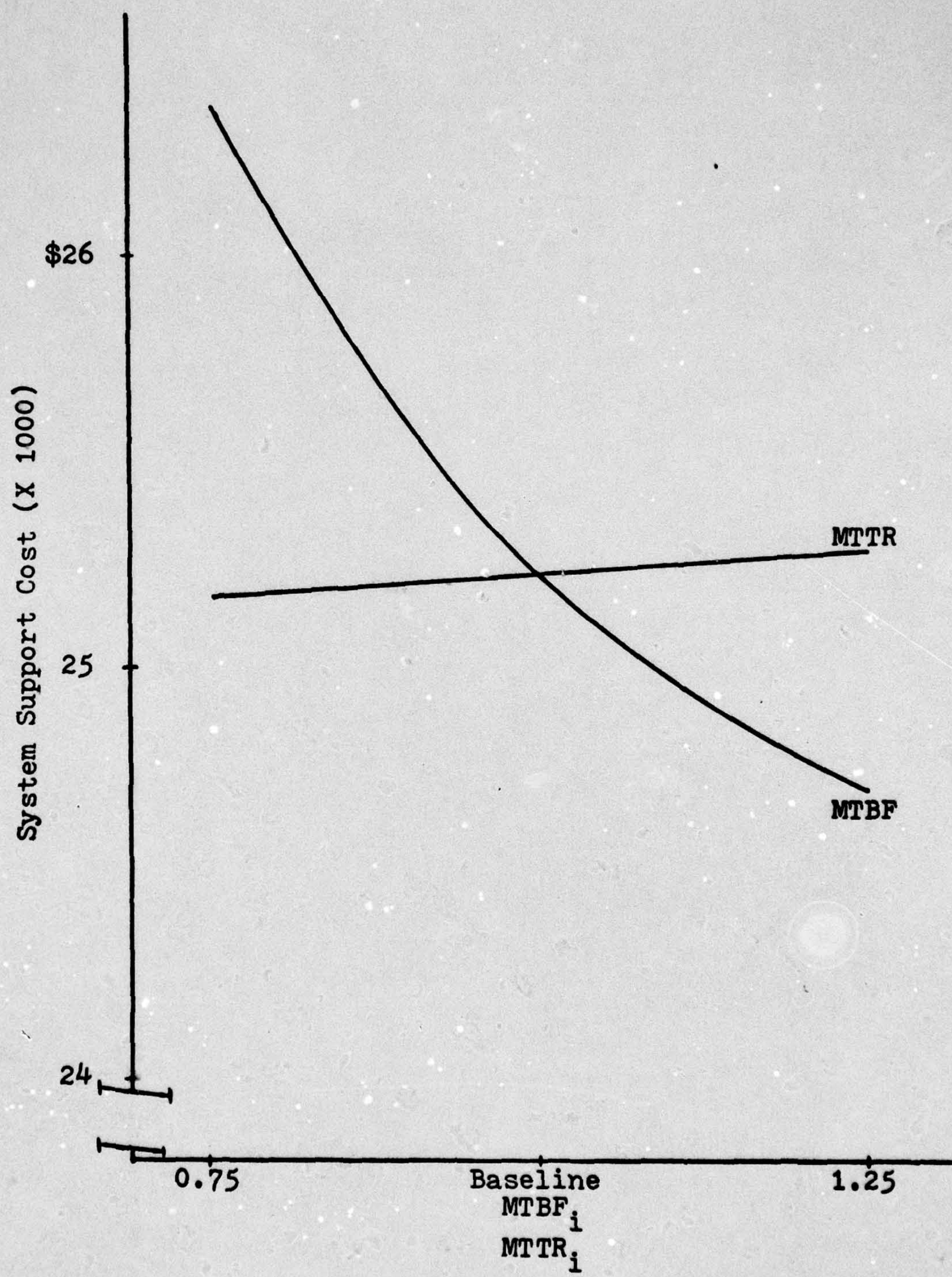

Figure 5. PRICE Sensitivity Results with Respect to Varying MTBF/MTTR

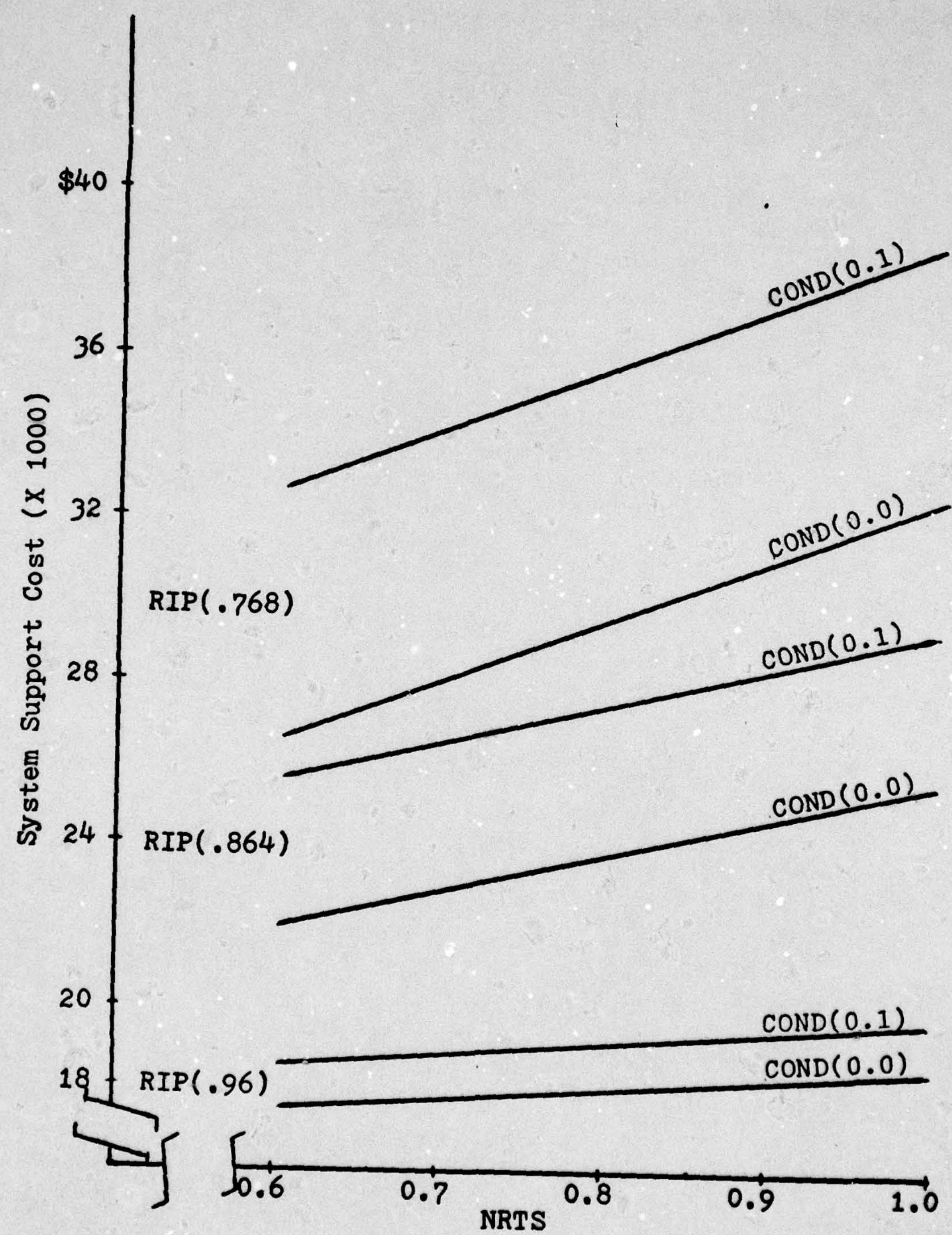

Figure 6. LSC Sensitivity Results
with Respect to Varying RIP, NRTS, RTS, COND

For every COND/RIP combination the NRTS rate was varied from 0.6 to 1.0. The only constraint on the allowable COND/NRTS/RTS combination is that a removed LRU is either condemned (COND), repaired at the base level (RTS) or not repaired at base level (NRTS) and sent to the depot (COND + RTS + NRTS = 1.0). As can be seen from the figure, decreasing the NRTS rate (for a given COND and RIP rate) decreases the system support cost at a constant rate. Also, the rate of change of system support cost increases as the RIP rate decreases. It is interesting to note that changing the COND rate from 0.0 to 0.1 (for a given RIP rate) has no effect on the rate of change of system support cost with the NRTS rate. For a given RIP rate, changing the COND rate from 0.0 to 0.1 only increased the system support cost.

Other parameters varied for PRICE L2 sensitivity analysis included the average number of parts replaced per repair (ANPR), and annual cost to maintain a part in the supply system (CAD). These two parameters were chosen particularly to investigate their effect on the overall support costs since ANPR and CAD values in particular were relatively uncertain during the data gathering effort.

Sensitivity analysis showed that as expected an increased parts usage rate increased the overall support costs. These increases are shown graphically in Figure 7 and in tabular form in Table XXIV. It is readily apparent from the table that changing ANPR caused changes in the supply and other cost categories only. This is logical since there are

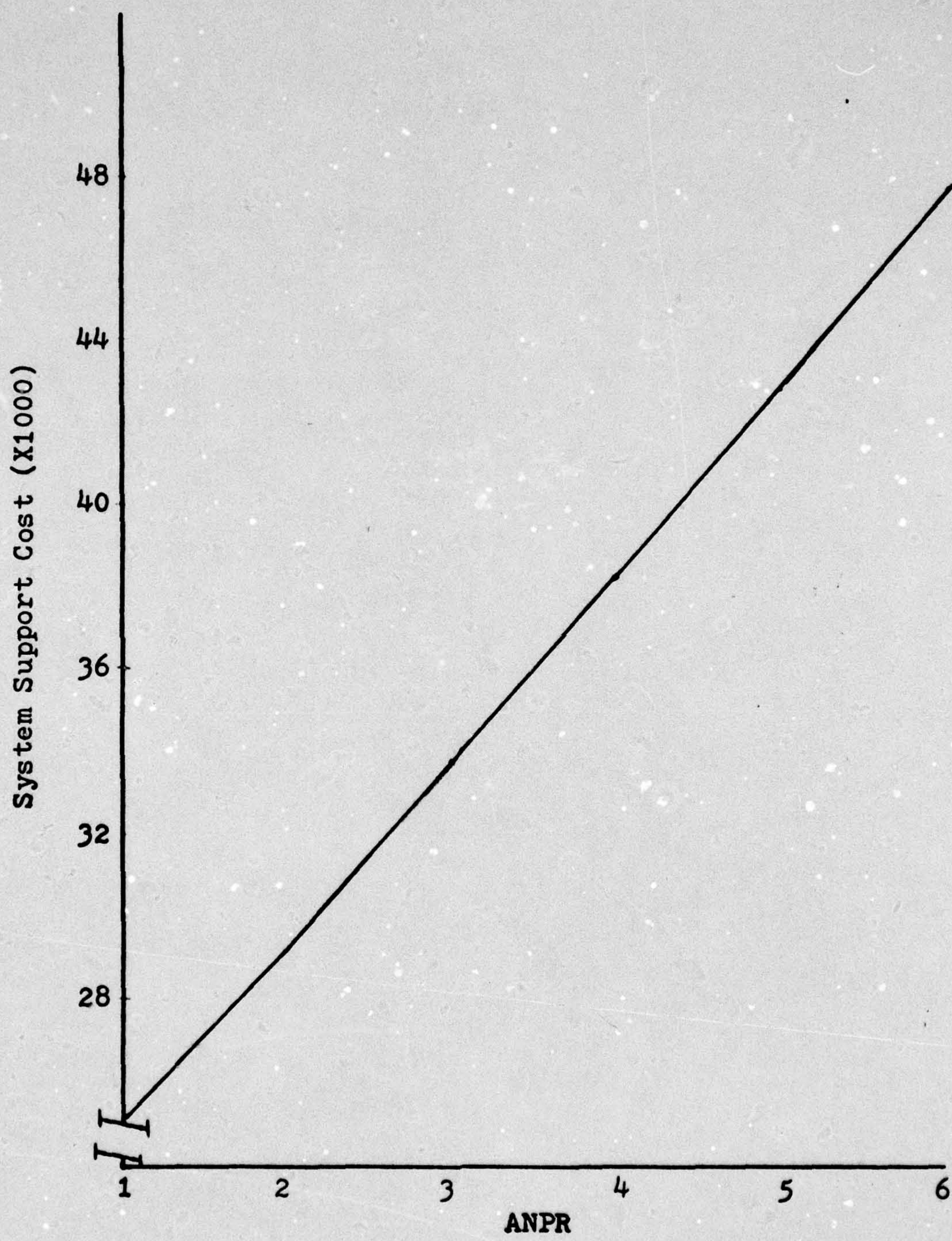

Fig 7. PRICE Sensitivity Results with Respect to Varying ANPR

TABLE XXIV

Changes in Support Costs as a Function of ANPR

Cost Category	ANPR					
	1 (Baseline)	2	3	4	5	6
SUPPORT EQUIP	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0
SUPPLY	2,301	6,394	10,908	15,459	20,026	24,571
SUPPLY ADMIN	21,700	21,700	21,700	21,700	21,700	21,700
MANPOWER	987	987	987	987	987	987
OTHER	44	87	133	178	223	266
TOTAL	25,032	29,168	33,728	38,324	42,936	47,524

no new part types in the supply system and MTBF and MTTR were held constant so the manpower and supply administration categories should not change. The other support costs category includes transportation costs which would be expected to increase with an increased parts usage.

CAD was set equal to $35 per part per year based upon a recommendation by Mr. George Kaufmann from RCA. He expressed that he had been advised by other PRICE L2 users that when modeling the Air Force Supply Agency for a system the default value of CAD = $100 is too high and CAD = $35 gives a better reflection of the supply administration costs. In checking this parameter's sensitivity, the parameter was changed to the default value of $100/item/year and the AFLC standard value of $166.25/item/year. As could be expected the support costs rose dramatically as a result of these changes. Total support costs were raised 160% from baseline for CAD = $100 and 325% for CAD = $166.25. A summary of PRICE L2 sensitivity analysis results is shown in Table XXV.

Other parameters varied for LSC sensitivity analysis included EBO, DMH, BMC, and DMC. Initially, a baseline value of 0.1 was assigned to the expected back order (EBO) level variable. This value was derived from AFCS parts availability objectives. On the baseline computer run the LSC model predicted a maximum back order level of 0.01 and then only for some of the LRUs. The effect on system logistic support (LSC) as EBO decreases below 0.01 is shown in Table XXVI.

Another uncertain baseline variable was depot mean time

TABLE XXV

PRICE L2 Sensitivity Analysis Summary

Paramater	Support Cost/Sys	ΔSupport Cost/Yr	Δ%
MTBF = 125% OF BASELINE	$ 24,704	$ - 525	- 2.00%
MTBF = 75% OF BASELINE	26,353	1,123	+ 4.50%
MTTR = 125% OF BASELINE	25,291	61	+ 0.24%
MTTR = 75% OF BASELINE	25,169	- 61	- 0.24%
CAD = $100	65,660	40,430	+ 160.00%
CAD = $166.25	106,403	81,371	+ 325.00%
ANPR = 2	29,168	4,136	+ 17.00%
ANPR = 3	33,728	8,696	+ 35.00%
ANPR = 4	38,243	13,211	+ 53.00%
ANPR = 5	42,936	17,904	+ 72.00%
ANPR = 6	47,524	22,492	+ 90.00%

TABLE XXVI

LSC Sensitivity With Respect to
Varying Expected Back Order (EBO) Level

EBO	LSC/System/Year
Greater than 0.01	$18,353
0.0100	18,461
0.0075	19,015
0.0050	22,446

to repair (DMH). The initial baseline value was derived from the H-036B depot maintenance data system. Since the H-036B data did not cover all of the LRUs within a given TACAN system a conservative average value of 25 hours was assigned to each LRU. The effect on system LSC as DMH increases above 25 hours is shown in Table XXVII.

TABLE XXVII

LSC Sensitivity With Respect to
Varying Depot Mean Time to Repair (DMH)

DMH (hrs.)	LSC/System/Year
25	$18,353
35	19,015
45	19,676

In addition to the list of model variables contained in chapter IV, BMC and DMC were the final LSC variables subjected to sensitivity analysis. They reflect the costs to stock and repair items below the LRU level at the base and depot respectively. Baseline values for these variables were obtained from Ssgt. Downey and Mr. Walther of the NAVAIDs maintenance shop, 2046th Communications Installation Group. The baseline values for BMC and DMC expressed as fractions of the LRU cost were 0.02 and 0.04. The effect on system logistics support cost as the variables were changed is shown in Table XXVIII.

TABLE XXVIII

LSC Sensitivity With Respect to Varying BMC/DMC

BMC/DMC	LSC/System/Year
.02/.04	$18,353
.03/.05	18,461
.04/.06	18,553

In general, the variables EBO, DMH, BMC, and DMC had little effect on the system logistics support cost. This fact is most probably due to the high LRU MTBFs and the TACAN maintenance environment in which 96 percent of all LRU failures are fixed on equipment.

Completeness

As was pointed out earlier the PRICE L2 model does not consider several of the cost categories included in the AFCS cost study. These costs included indirect personnel, PCS, BOS, Training and Miscellaneous personnel support costs. Additionally, PRICE L2 does not consider dedicated personnel for TACAN maintenance and due to this fact, manpower costs predicted by PRICE L2 are quite low. All of these costs could have a significant impact on whether an existing system should be continued, modified or replaced since the latter two options in particular could require extensive training or retraining expenses for the maintenance personnel.

With regard to the ten elements of integrated logistics support, PRICE L2 considers at least five of the elements to some degree. The elements considered are Maintainability and Reliability, Support and Test Equipment, Supply Support, Transportation and Handling and Personnel and Training. Due to the proprietary nature of the PRICE models it is not possible to discuss these elements in detail but they are considered internally by the model. Support and Test equipment costs for the TACAN systems being considered are zero due to input variables being zeroed out before the runs were made. This was done since the systems being analyzed do not have LRU unique support and test equipment.

In comparison to the PRICE L2 model, the LSC model addresses eight of the ten elements of Integrated Logistic Support identified in chapter I. The elements considered by the

LSC model (and the specific LSC equations that address each element) are Maintainability and Reliability (equations 1, 2, 3), Support and Test Equipment (equation 5), Supply Support (equation 4), Transportation and Handling (equation 3), Technical Data (equation 7), Facilities (equation 8), Personnel and Training (equation 6), and Management Data (equations 7, 4). Based on the completeness criteria and considering the LSC model's intended use to differentiate between alternative designs and to analyze support cost aspects of design trade decisions, the LSC model appears quite complete. However, as is evident by the disparity between the model predicted costs and the actual experienced costs, the LSC model is not complete when considering the reality of the budgeted cash outlays required to support a system.

Documentation

A cost model's documentation plays a very important role in facilitating use of the model. If adequate documentation is not provided for a model any user will almost certainly run into difficulties in attempts to utilize the model.

The PRICE models used are in general well documented, however, there was an amount of uncertainty concerning the meaning of specific variables and input requirements. A large part of the documentation difficulties experienced are explainable by the lack of training in the models use. RCA provides users with a school for both PRICE and PRICE L2 which was not attended by either of the individuals performing this analysis. Although the lack of training did cause some

difficulties in model usage the difficulties encountered were not insurmountable and should not invalidate this study's findings.

Two sets of documentation of the LSC model were evaluated in this study. The LSC model accessed via SAVE is not well documented at this time. This fact precluded evaluation of the LSC model via the SAVE program. The documentation problems within SAVE are not overwhelming but they need to be corrected before the full potential of the SAVE program can be utilized.

The LSC model accessed via the AFLC CREATE system is well documented. This is evident by the fact that the LSC model validation and sensitivity analysis efforts were accomplished on the CREATE system late in this thesis effort after transitioning from SAVE. While we feel that the LSC model is well documented, we recommend direct contact with the LSC model developers and users at AFLC for first time users in order to reinforce and augment the information contained in the model user's handbook.

In this chapter, the results of the LSC and PRICE model evaluation efforts were presented. The results were discussed in the framework of the desirable model characteristics of availability of input data, validity, sensitivity, completeness, and documentation. The conclusions and recommendations derived from the methodology and results of this thesis effort are the subject of the final chapter.

VI Conclusions and Recommendations

Conclusions

A summary of the conclusions derived from this model evaluation effort are displayed in Table XXIX. The table reflects model ratings in each of the five listed model characteristics and the criterion assigned to each characteristic. The numerical ratings also reflect our subjective judgement based on the knowledge gained in working with the LSC and PRICE cost models for the past six months. Additionally, each characteristic is subjectively weighted by its importance to the decision maker when using the model as a tool in decision making for decisions involving system retention, modification or replacement. Validity was felt to be the most important model characteristic followed in decreasing order of importance by availability of input data, completeness, sensitivity, and documentation. Within each model characteristic, each model was assigned a relative score by multiplying rating by weight. Based on Table XXIX, both the LSC and PRICE models received essentially equal scores on their overall applicability to the CEM systems and environment addressed by this study. Note that each model received an identical rating in validity. Validity was assessed by adding to the model predicted system support cost an adjustment before making a comparison with AFCS Cost Study results. The adjustment consisted of the costs in those cost categories included in the cost study but not included in the models.

TABLE XXIX

Model Evaluation Summary

Model Characteristic	Criteria	Rating Scale	Weight	Raw Score		Relative Score	
				PRICE	LSC	PRICE	LSC
COMPLETENESS	10 Elements of Integrated Logistics Support	1-10	3	5	8	15	24
SENSITIVITY	Sensitivity to Variables Affecting Decision Issue	1-10	2	6	6	12	12
VALIDITY	Comparison with AFCS Cost Study	1-10	5	8	8	40	40
AVAILABILITY OF DATA	Number of Sources and Availability Within Each Source	1-10	4	8	6	32	24
DOCUMENTATION	Amount of Direct Contact Required with Model Developer	1-10	1	7	9	7	9
						106	109

The model predicted system support cost plus adjustments, when compared to the cost study results, provide the measure of validity. Both models appear valid for the TACAN systems.

Beyond the specific conclusions summarized in Table XXIX the following conclusions are presented:

1. While the LSC and PRICE models do appear to be applicable to the TACAN systems in the CEM environment, we do not feel qualified to generalize beyond our findings to other CEM equipment. However, we do feel that as CEM systems are updated and modernized, and as the CEM environment approaches the environment discussed in the introduction, the LSC and PRICE models will become even more applicable. We feel this way because the future CEM systems and environment will more closely resemble the present aircraft systems and environment in which the LSC and PRICE models have been proven valid.
2. The model variables in both the LSC and PRICE models are sufficiently flexible to allow for accurate representation of the system's actual operational and maintenance environments based upon interrelated sets of mathematical relationships.
3. The LSC model is sufficiently flexible and simple that changes can be readily made in order to even more accurately describe the actual environment.
4. Price L does not allow for changes to model equations, however, the flexibility built into the overall system should allow for an accurate representation

of most situations.

5. In situations when explicit input values for new systems are required, the PRICE system of models would appear to be a better tool since they will generate an input file for the life cycle cost model. LSC, on the other hand, requires explicit inputs in all cases.

Finally, we concluded that these models should not be used for budgetary purposes since not all of the cost elements required for accurate budgeting are included in either model. It was also noted that operational requirements often dictate workcenter manning figures rather than workload. This factor alone could (and does) cause a non-design or engineering parameter, not considered by these models, to be a system's support cost driver. In the case of the TACAN systems studied personnel related costs accounted for approximately 80% of the experienced annual support cost associated with each system.

Recommendations

Based upon our feelings and experiences in using these cost models several recommendations will be made.

1. A further cost study should be performed using AFCS/AFLC data resources to compute personnel costs based upon actual maintenance man-hours. This new study would allow for a more accurate comparison of experienced costs and cost model predictions.
2. Any further attempt to use these models should

include initial contacts with the model developers to explain the question being investigated and to gain their expertise in the best way to proceed.

3. Adapt the LSC model to the CEM environment by excluding non-applicable considerations in the present LSC model, such as jet engine data, and including AFCS peculiar considerations, such as mobile depot maintenance and power costs. (NOTE: This model adaptation effort should consider using the 1979 version of the LSC model which also considers software related costs).
4. A project should be undertaken to correct the deficiencies discovered in the SAVE interactive graphics computer software package. Once current SAVE problems are corrected, the LSC model within SAVE should be exercised using the data from this effort. (NOTE: Based upon the findings of this effort AFAL is currently contracting an effort with the SAVE developers to correct current deficiencies).
5. A follow-on effort should compare the LSC and PRICE models to the new cost model being developed by the Sacramento ALC for upcoming TACAN modifications.
6. A follow-on effort should be conducted which concerns itself only with the sensitivity issue for each variable used in the LSC model. This effort should not address data ambiguity, rather it should investigate all LSC variables and determin those that have a signigicant effect on the logistic support cost.

7. Conduct a follow-on study using the new version of PRICE to generate an input file for PRICE L2 to investigate whether the new version of PRICE provides a better input file for PRICE L2 and thus a better operations and support cost estimate.

Bibliography

Adel, Robert E., William J. Bonner, and Keith J. Gibson. Three Life Cycle Cost Models for Inertial Systems. April 1974. (AD A000 483)

AFLCP 57-13. Recoverable Inventory Control Using MOD-METRIC. AFLC Headquarters, Wright-Patterson AFB, Ohio, 28 Feb 1975.

AFLCR 66-15. Equipment Maintenance/Product Performance. Washington, D.C., Department of the Air Force, 23 Aug 74.

AFP 800-7. Integrated Logistics Support Implementation Guide for DOD Systems and Equipment. Washington, D.C.: Department of the Air Force, March 1972.

AFR 173-10. USAF Cost and Planning Factors. Volume I, Washington, D.C.: Department of the Air Force, 6 Feb 75.

AFR 400-63 Volume I. Communications-Electronics Logistics Support Cost Management Program. Washington, D.C., Department of the Air Force, 26 May 78.

AFR 400-63 Volume II. Communications-Electronics Logistics Support Cost Management Program/Procedural Guide for Tracking and Projecting Support Costs. Washington, D.C., Department of the Air Force, 9 Feb 79.

Air Force Logistics Command. Logistics Support Cost Model User's Handbook. Wright-Patterson AFB, Ohio, August 1976.

Air Force Logistics Command. Logistics Support Cost Model User's Handbook. Wright-Patterson AFB, Ohio, January 1979.

Baron, David A. and Robert E. Mortenson Jr. A Logistic Life Cycle Support Cost Model. SLSR-5-69 (thesis). Air Force Institute of Technology, Wright-Patterson AFB, Ohio, August 1969. (AD 863 842)

Bennett, John J., Dr. "Industry Feedback on Life Cycle Cost," Defense Management Journal. Vol 12(4). Washington, D.C. October 1976.

Blanchard, Benjamin S. Design and Manage to Life Cycle Cost. Portland, Oregon: M/A Press, 1978.

-----Logistics Engineering and Management. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1974.

Boden, William H. "Designing for Life Cycle Cost," Defense Management Journal. Volume 12(1). Washington, D.C. January 1976.

Buckley, Jerry Lee. Operating and Support Costs: An Army Perspective. May 1977. (AD A042 963)

Collins, Dwight E. Analysis of Available Life Cycle Cost Models and Actions Required to Increase Future Model Applications. June 1975. (AD A014 772)

-----Analysis of Available Life Cycle Cost Models and Their Application. Joint AFSC/AFLC Commander's Working Group on Life Cycle Cost (ASD/ACL), Wright-Patterson AFB, Ohio, June 1976.

-----"Models A Key to Air Force Life Cycle Cost Implementation," Defense Management Journal. Vol 12(1). Washington, D.C. January 1976.

Cork, Thomas R. and Joan F. Mulcahy. System Avionics Value Estimation (SAVE): An Aid for Avionics Logistics-and-Support Cost Analyses. Technical Report AFAL-TR-77-179. Prepared by Battelle's Columbus Laboratories for AFSC/AFAL, Wright-Patterson AFB, Ohio, September 1977.

Cork, Thomas R., David W. Welp, and Michael A. Duffy. Definition of a Systematic Cost and Logistics Effectiveness (SCALE) Procedure. Technical Report prepared by Battelle's Columbus Laboratories for Headquarters AFLC, Wright-Patterson AFB, Ohio, November 1975.

Department of Defense. Integrated Logistics Support Planning Guide. DOD 4100.35G. Washington, D.C.: Government Printing Office, 15 October 1968.

Dover, Lawerence E. and Billie E. Oswald Jr. A Summary of Selected Life Cycle Costing Techniques and Models. SLSR-18-74B (thesis), Air Force Institute of Technology, Wright-Patterson AFB, Ohio, August 1974. (AD 787 183)

Eaton, Elbridge P. "Lets Get Serious About Total Life Cycle Costs," Defense Management Journal. Vol 12(1). Washington, D.C. January 1977.

ESD Guide to Life Cycle Cost (LCC) In Source Selection. September 1976. (AD A039 325)

Fiorello, Marco R. Getting "Real" Data For Life-Cycle Costing. January 1975. (AD A010 960)

-----Estimating Life Cycle Costs: A Case Study of the A-7D. February 1975. (AD A011 643)

Fiorello, Marco R., et al. An Appraisal of Logistics Support Cost Used in the Air Force IROS Program. February 1975. (AD A009 844)

Gable, Grant E. "Capitalizing on Cost-Reducing Opportunities, Defense Management Journal. Vol 13(1). Washington, D.C. January 1977.

Gates, Robert K., et al, Program LCC Documentation Version 2, prepared by The Analytic Sciences Corporation (TASC) for the Aeronautical Systems Division, Wright-Patterson AFB, Ohio, April 1976.

Gibson, John D.S. and Brian S. Mills. Life Cycle Cost Management Guidance for Program Managers (Fourth Edition). Comptroller (Directorate of Cost Analysis), Aeronautical Systems Division, Wright-Patterson AFB, Ohio, July 1978.

Gibson, John D.S. and Brian S. Mills. Understanding and Evaluating Life Cycle Cost Models (Second Edition). Comptroller (Directorate of Cost Analysis), Aeronautical Systems Division, Wright-Patterson AFB, Ohio, March 1977.

Hill, Vaughn E. and Paul L. Martin Jr. Life Cycle Costing Its Promise and Problems. Air War College, Air University, Maxwell AFB, Alabama. April 1976.

Hockett, J.M., et al. Life Cycle Cost/Design-to-Cost Guidelines. June 1975. (AD B006916L)

Introduction to Life Cycle Costing. Class notes from QM 5.59, School of Systems and Logistics. Air Force Institute of Technology, Wright-Patterson AFB, Ohio.

Johnston, Douglas M. "Men, Myths, and Machine or All the Ships at Sea," Defense Management Journal. Vol 12(4). Washington, D.C. October 1976.

Joint Design-to-Cost Guide -- Life Cycle Cost As a Design Parameter. October 15, 1977. (AD A048 254)

Katz, Irving, and Raymond E. Cavender. Weapon System Life Cycle Costing. July 1971. (AD 729 866)

Kaufmann, George A. The Programmed Review of Information for Costing and Evaluation (PRICE) Life Cycle Cost Model. RCA Corporation, Cherry Hill, N.J., March 1978.

King, E.P. Existing Computer Aids for Logistics Analysis. February 1974. (AD B001 677L)

-----Requirements for Computer Aided Logistics Analysis. November 1973. (AD B001 676L)

Knight, C.R. "Warranties As A Life Cycle Cost Management Tool," Defense Management Journal. Vol 12(1). Washington, D.C. January 1976.

Koch, Charles M. Life Cycle Costing of Fixed Place Equipment. May 1970. (AD 739 006)

Lange, Gunther, et al. Life Cycle Costing: Problems, Policies, and Prospects. March 1970. (AD 875 909)

Life Cycle Costing in System Acquisition. November 1969. (AD 699 191)

Mc Guire, Thomas E. Cost Analysis--What Is It, What Should It Be. May 1970. (AD 912 083L).

Meitzler, Thomas D. AGMC LCC Model for Inertial Navigation Systems. October 1975. (AD A016 626)

Menker, Lavern J. Life Cycle Cost Analysis Guide. Joint AFSC/AFLC Commander's Working Group on Life Cycle Cost (ASD/ACL), Wright-Patterson AFB, Ohio, November 1975.

Nixon, Harvey L. Jr., and Charles B. Hitchcock. A Simulation of the Reparable Processing Procedures Applicable to Reliability Improvement Warranties. August 1975. (AD A016 038).

O'Flaherty, John. Weapon System Cost Model Objectives. April 1971. (AD 883 277)

Patterson, Michael L. Integrated Logistic Support Costs. Febrary 1971. (AD 880 878).

Perschbacher, P.G. Life Cycle Costs in the Acquisition of Weapon Systems. April 1974. (AD 918 906L).

PRICE Reference Manual RCA/PRICE Systems, Camden N.J. 08101 1977.

Reference Manual PRICE Life Cycle Cost Model, RCA/PRICE Systems, Cherry Hill N.J., Sept 1977.

Rose, Galen J. Demonstration of a Logistics Support Cost Model for Stage III of the Digital European Backbone Program. GSM/SM/76S-22 (thesis). Air Force Institute of Technology, Wright-Patterson AFB, Ohio, September 1976.

Schuck, Paul E. Jr. Life Cycle Costing at the Program Office Level. Air University, Maxwell AFB, Alabama. April 1978.

Shorey, Russell R. "Managing Downstream Acquisition Costs," Defense Management Journal. Vol 12(1). Washington, D.C. January 1976.

Singu, Robert A. Acquiring Affordable Weapon Systems. May 1977. (AD A042 777)

Stansberry, J.W. "Source Selection and Contracting Approach to Life Cycle Costing," Defense Management Journal. Volume 12(1). Washington, D.C. January 1976.

Stimson, Richard A., and Marilyn S. Barnett. "Buying Commercial: Why Not?," Defense Management Journal. Volume 12(4). Washington, D.C. October 1976.

Support of Air Force Automatic Data Processing Requirements through the 1980's. June 1974. (AD 783 768)

Turek, John P., et al, Predictive Operations and Maintenance Cost Model. Technical Report AFAL-TR-78-49 Volume I,II,III. Prepared by Westinghouse Electric Corporation for the Air Force Avionics Laboratory Systems Evaluation Group, Wright-Patterson AFB, Ohio, April 1978.

Tyburski, D.A., and R.D. White. Generalized Electronics Maintenance Model (GEMM). U.S. Army Electronics Command, Fort Monmouth, N.J., November 1971.

Young, Thomas C., and John F. Feist. A Study of the Application of Integrated Logistics Support in the Conceptual Phase of Weapon System Acquisition. SLSR-25-70 (thesis). Air Force Institute of Technology, Wright-Patterson AFB, Ohio, August 1970.

Appendix A

Models Reviewed During SCALE Project

Table A-I

Models Reviewed

Name/Date	Acronym	Developer
Army Operating and Support Costing Guide (1974)	Army O&S	Comptroller, Department of the Army
Automated Life Cycle Cost Models for Army Weapon Systems (1969)	Army LCC	U.S. Army Weapons Command
Avionics Evaluation Program (1969)	AEP	U.S. Air Force Avionics Laboratory (AFAL)/Battelle
BOMTAN: A Model for Estimating the Annual Cost of Bomber and Tanker Squadrons (1974)	BOMTAN	Rand
Computer Model for Economic Analysis of Army Aircraft RAM Improvement Proposals (1974)	Army RAM	U.S. Army Aviation Systems Command (AVSCOM)
Cost Analysis of Avionics Equipment (1974)	CAAE	AFAL/General Research Corp.
Cost Analysis Improvement Group's Operating and Support Costing Guide (1974)	CAIG O&S	Office of Secretary of Defense
Cost Effectiveness Plan for Joint Tactical Communications Program Life Cycle Costing (1974)	TRI-TAC LCC	Joint Tactical Communications Program Office

Table A-I (Continued)

Name/Date	Acronym	Developer
Criteria for Evaluating Weapon System Reliability, Availability and Costs (1974)	LMI Task 73-11	Logistics Management Institute
Design to System Performance/Cost (1973)	DSPC	U.S. Air Force Systems Command (AFSC)
Discard/Repair Cost Analysis (1971)	D/RC	U.S. Army Missile Command (MICOM)
Generalized Effectiveness Methodology (1973)	GEM	U.S. Navy Materiel Command
Generalized Electronics Maintenance Model (1971)	GEMM	U.S. Army Electronics Command
Inertial Navigation Systems Life Cycle Costing (1974)	INS-LCC	U.S. Air Force Guidance and Meteorology Center
Logistics Composite Model (1969)	L-COM	U.S. Air Force Logistics Command (AFLC)/Rand
Logistics Cost Analysis Model (1969)	LOCAM	MICOM
Logistics Support Cost Model (1973)	LSC	AFLC
Military Standard Level of Repair (1973)	MIL-STD	Department of the Navy

Table A-I (Continued)

Name/Date	Acronym	Developer
Mission Completion Success Program (1973)	MCSP	AFSC
Modified METRIC Program (1972)	MOD-METRIC	AFLC (Rand Developed METRIC)
Naval Air Development Center (NADC) Life Cycle Costing Program (1973)	NADC-LCC	NADC
Optimization of Time Between Aircraft Overhauls (1975)	OTBAO	AVSCOM
Optimum Repair Level Analysis (1970)	ORLA	AFLC
Powered Lift STOL Performance Model (1973)	PLSPM	NASA/Battelle
Use of Models in Level-of-Repair Decisions (1973)	AFHRL-LOR	U.S. Air Force Human Resources Laboratory
Warranties for Defense Avionics Procurements (1973)	Warranties	Rome Air Development Center/ ARINC

Appendix B

Brief Descriptions of the Models

Included in SAVE

Appendix B

Brief Descriptions of the Models Included in SAVE

CACE (Ref AFR 173-10, 1975)

This model is the primary tool used by the Air Force in the Defense Systems Acquisition Review Council (DSARC) process. It aggregates the cost to operate and support a squadron at the base level. Of primary interest is the size of the maintenance work force and the operational crew size/ratios. Other support costs included are the apportioned base support and operational support personnel. In the DSARC process, the comparison of what it costs now for a certain capability to the projection of what it will cost to operate a squadron of new systems is becoming a more significant factor. In early stages, these costs will play a role in defining the affordability limit for a new system being designed to Life Cycle Costs.

The CACE computer model included in the SAVE processor was developed by AFLC and uses the AFR 173-10 equations. In addition to the equations from AFR 173-10, an optional manpower algorithm is included which generates a squadron manpower package (Ref Cork, 1977:9).

LSC (Ref AFLC LSC Model User's Handbook, 1976)

The AFLC Logistics Support Cost (LSC) Model is used to estimate the expected support costs that may be incurred by adopting a particular design. The LSC model addresses only support costs and is basically a set of ten cost equations,

each of which represents a cost of resources necessary to operate the logistics system. The ten cost components are:

1. Initial and replenishment FLU/LRU spares cost
2. On-equipment maintenance cost
3. Off-equipment maintenance cost
4. Inventory management cost
5. Support equipment cost
6. Personnel training cost
7. Management and technical data cost
8. Facilities cost
9. Fuel consumption cost
10. Spares cost (engines)

The first eight equations are structured to aggregate the cost of each subsystem within a system including the subordinate FLUs (first level replaceable units) and support equipment. Equations nine and ten compute costs unique to propulsion subsystems only.

In cross referencing from SAVE to the LSC documentation, the user may be confused by the terms LRU and FLU. AFLC developers of LSC have generated the term FLU (first level replaceable unit) in order to generalize the term for items which are not physically removed at the "flight line" where "flight line" is synonomous with the term "line" in line replaceable unit (LRU).

The LSC model is intended for use in two ways:

1. To differentiate between alternative designs
2. To analyze support cost aspects of design trade decisions

Perhaps the most significant variable and principal connecting factor in the LSC model is the reliability parameter (mean time between failure-MTBF) of FLUs/LRUs which appears in seven of the equations. The time units for measuring MTBF are equipment operating hours in the operational environment.

The LSC model output is formatted in a manner which allows accumulation of the cost/quantity measures at several levels of indenture (e.g., system, subsystem, LRU levels). The standard on-line LSC output consists of the life cycle costs broken down into six SAVE cost categories. Optional on-line LSC output consists of life cycle costs by level 1 subsystem. In the off-line print mode, the entire detailed output of the LSC model is available.

<u>LCC-2</u> (Ref Gates, 1976)

Program LCC is a life cycle cost analysis program developed to evaluate the combined costs of acquiring an avionics system and supporting it over its operational life. Cost comparisons can be used in the selection of the appropriate hardware mechanization alternatives as well as in the evaluation of various maintenance philosophies for the system. Typical life cycle analyses that can be conducted using program LCC include:

1. Comparative evaluation of alternative support concepts including the Reliability Improvement Warranty

2. Investigating sensitivity of life cycle cost to uncertain parameters (MTBF, Turnaround Time, Usage Rate, etc.)

3. Determination of spares quantities that must be provided at the base and depot levels to meet system

availability objectives

4. Optimum Repair Level Analyses that are optimized at the system rather than the replaceable unit level

5. Identification of the important cost driving parameters in a system acquisition program

6. Estimation of manpower requirements at each repair level

The life cycle cost evaluation framework is provided by a mathematical model constructed to estimate life cycle cost for a given set of assumptions (scenario). The comprehensive support model is formulated to address not only support cost estimation issues but also issues pertaining to Integrated Logistic Support planning (Ref Gates, 1976:1-2).

GEMM (Ref Tyburski, 1971)

The GEMM model considers the life cycle costs of a procurable subsystem where the subsystem can be defined down to the sub-SRU level. If detailed design data is available, GEMM can be used to evaluate the quantities of personnel (by skill types) and support equipment (by types) at each level of maintenance.

In addition to the standard three levels of maintenance, GEMM is structured in a manner which allows consideration of a theatre level of support between the base and depot.

The spares algorithm includes several specifically definable time segments of the general "maintenance turnaround time" used by LSC, LCC-2, and MOD-METRIC. Among these are the "awaiting maintenance time" data items for each of the four levels.

GEMM also treats equipment availability using the classi-

cal definition of availability of $A = \frac{MTBF}{MTBF + MTTR}$ (Ref Cork, 1977:14).

<u>MOD-METRIC</u> (Ref AFLCP 57-13, 1975)

MOD-METRIC is a mathematical model used to analyze a multi-item, multi-echelon, multi-indenture inventory system for recoverable items. Its objective is to minimize expected back orders for an end item subject to an investment constraint on the total dollars allocated to both the end item and its components. A back order is defined to exist at a point in time if and only if there is an unsatisfied demand at base level (e.g., a recoverable item is unavailable for an aircraft which makes that aircraft not operationally ready). MOD-METRIC permits the explicit consideration of a hierarchical parts structure.

MOD-METRIC can be used for optimizing new procurement, evaluating an existing stock distribution, and redistributing system stock between the bases and depot. It can only be applied in situations where there is no lateral resupply between bases. The model assumes that the repair level (i.e., base versus depot) is a function of complexity only, independent of existing workload. MOD-METRIC does not have the capability of determining maintenance costs, training costs, or shipping costs for either LRUs or SRUs (Ref Cork, 1977:14).

Appendix C

<u>SAVE Data Requirements (LSC)</u>

Appendix C

SAVE Data Requirements (LSC)

LSC, LEVEL 0

WEAPON SYSTEM DEPLOYMENT, USAGE AND CHARACTERISTICS

Weapon System Deployment

		Lower Limit	Upper Limit	Value
1	EXPECTED OPERATIONAL LIFE (YRS)	* 1.	25. *	______
2	SYSTEMS DEPLOYED IN CONUS (QTY)	* 0	1000	______
3	SYSTEMS DEPLOYED OVERSEAS (QTY)	* 0	1000	______
4	OPERATING BASES IN CONUS (QTY)	* 0	75	______
5	OPERATING BASES OVERSEAS (QTY)	* 0	50	______
	Mission Utilization			
1	PEACETIME FLYING (HOURS/SYSTEM/ MONTH)	* 1.	730. *	______
2	WARTIME PEAK FLYING (HOURS/SYSTEM/ MONTH)	* 0.	730. *	______
	Equipment Characteristics			
8	AVIATION FUEL (lbs/CONSUMED/ FLYING HR)	* 0.	1000.	______
9	AVIATION FUEL (COST/lb CONSUMED)	* 0.	100.	______
	MAINTENANCE RATES, ACTIVITIES AND COSTS			
	Corrective Action Activities and Costs			
5	ON-EQUIP MAINT DOCUMENTATION (MHRS/ACT)	* 0.	1.	______
6	OFF-EQUIP MAINT DOCUMENTATION (MHRS/ACT)	* 0.	1.	______

* Fixed Limit

LSC, LEVEL 0 (Continued)

PERSONNEL-OPERATIONS, MAINTENANCE AND TRAINING

Personnel Requirements

		Lower Limit	Upper Limit	Value
10	BASE AIRMEN, ANNUAL TURNOVER RATE	* 0.	1. *	________
11	DEPOT PERSONNEL, ANNUAL TURNOVER RATE	* 0.	1. *	________
21	DIRECT PRODUCTIVE MHRS/MNYR, BASE, (QTY)	* 0.	2080.	________
22	DIRECT PRODUCTIVE MHRS/MNYR, DEPOT (QTY)	* 0.	2080.	________

SPARES-INITIAL AND REPLENISHMENT

Stockage Objectives

		Lower Limit	Upper Limit	Value
1	EXPECTED BACKORDER LEVEL	* .01	1.	________

Computational Time Factors

		Lower Limit	Upper Limit	Value
1	ORDER AND SHIPPING TIME, CONUS (DAYS)	* 0.	30.	________
2	ORDER AND SHIPPING TIME, OVERSEAS (DAYS)	* 0.	30.	________

LOGISTICS OPERATIONS

Supply Management Factors

		Lower Limit	Upper Limit	Value
1	INITIAL ITEM MGT ENTRY COST ($/NEW ITEM)	* 0.	70.	________
2	RECURRING ITEM MGT COST ($/ITEM/YR)	* 0.	150.	________

* Fixed Limit

LOGISTICS OPERATIONS
(Continued)

Supply Management Factors
(Continued)

		Lower Limit	Upper Limit	Value
3	BASE SUPPLY MGT COST ($/ITEM/YR)	* 0.	50.	________
4	LABOR TIME/SUPPLY TRANSACTION (MHRS/ACT)	* 0.	1.	________
	Transportation Factors			
1	PACKING AND SHIPPING, CONUS ($/LB)	* 0.	1.	________
2	PACKING AND SHIPPING, OVERSEAS ($/LB)	* 0.	2.	________
3	TRANSPORTATION RECORDS LABOR (MHRS/ACT)	* 0.	1.	________
	Technical Orders			
3	INITIAL COST OF TECH ORDERS ($/PAGE)	* 0.	300.	________

* Fixed Limit

LSC, LEVEL 1

WEAPON SYSTEM DEPLOYMENT, USAGE AND CHARACTERISTICS

Weapon System Deployment

		Lower Limit	Upper Limit	Value
5	STOCKAGE LOCATIONS FOR SPARE ENGINES (QTY)	* 0.	75	______

Equipment Characteristics

		Lower Limit	Upper Limit	Value
3	SYSTEM ACQUISITION COST, SPARES ($/UNIT)	* 1.	200000.	______
9	QUANTITY OF ITEM/NEXT HIGHER ASSEMBLY	* 1	10	______
10	WORK UNIT CODE (5 NUMERIC DIGITS)	* 0	99999*	______

MAINTENANCE RATES, ACTIVITIES AND COSTS

Reliability and Maintenance Rate Factors

		Lower Limit	Upper Limit	Value
1	MEAN OP TIME BETWEEN PREV MAINT ACT (HRS)	0.	10000.	______
2	MEAN OP TIME BETWEEN CORR MAINT ACT (HRS)	0.	10000.	______
3	MEAN OP TIME BETWEEN OVERHAUL (HRS)	0.	100000.	______

Level of Repair

		Lower Limit	Upper Limit	Value
3	SYS FAILURES FIXED BY LRU REMOVAL (FRAC)	* 0.	1. *	______

* Fixed Limit

LSC, LEVEL 1 (Continued)

MAINTENANCE RATES, ACTIVITIES AND COSTS
(Continued)

Corrective Action Activities and Costs

			Lower Limit	Upper Limit	Value
4	REMOVE, REPLACE, CHECKOUT, ON-EQUIP (MHRS)	*	0.	5.	________
7	MATERIAL COST/LABOR HOUR, BASE ($/HR)	*	0.	20.	________
8	MATERIAL COST/LABOR HOUR, DEPOT ($/HR)	*	0.	20.	________
	Scheduled Maintenance Actions and Costs				
1	PERIODIC/PHASED MAINTENANCE TIME (MHRS)	*	0.	8.	________
2	OVERHAUL COST ($)	*	0.	10000.	________
	PERSONNEL-OPERATIONS, MAINTENANCE AND TRAINING				
	Personnel Requirements				
5	MNHRS/MO AVAILABLE, BASE LEVEL (QTY)	*	0.	200.	________
6	MNHRS/MO AVAILABLE, DEPOT LEVEL (QTY)	*	0.	200.	________
	Personnel Costs				
1	MAINTENANCE LABOR RATE, BASE LEVEL ($/MHR)	*	0.	25.	________
2	MAINTENANCE LABOR RATE, DEPOT ($/MHR)	*	0.	35.	________
15	TRNG COST OF BASE LEVEL SKILLS ($/MAN)	*	0.	5000.	________
16	TRNG COST OF DEPOT LEVEL SKILLS ($/MAN)	*	0.	5000.	________

* Fixed Limit

LSC, LEVEL 1 (Continued)

SPARES-INITIAL AND REPLENISHMENT

Stockage Objectives

			Lower Limit	Upper Limit		Value
1	SPARES OBJECTIVE, HDW LEVEL 2 ITEMS (FRAC)	*	.01	.99		________

Computational Time Factors

			Lower Limit	Upper Limit		Value
1	BASE REPAIR CYCLE TIME (DAYS)	*	0.	15.		________
3	DEPOT REPAIR CYCLE TIME (DAYS)	*	0.	60.		________
11	TRANSPORT TIME, BASE-DEPOT, CONUS (DAYS)	*	0.	30.		________
12	TRANSPORT TIME, BASE-DEPOT, OVER-SEAS (DAYS)	*	0.	45.		________
33	ENGINE AUTOMATIC RESUPPLY TIME (DAYS)	*	0.	30.		________

SUPPORT EQUIPMENT AND FACILITIES

Support Equipment Costs

			Lower Limit	Upper Limit		Value
1	NUMBER OF SE TYPES REQUIRED(QTY)	*	0	10	*	________
3	COST/SET OF SE TYPE 1 ($)	*	0.	100000.		________
4	ANNUAL COST, SE TYPE 1 (FRAC OF COST/SET)	*	0.	1.	*	________
5	COST/SET OF SE TYPE 2 ($)	*	0.	100000.		________
6	ANNUAL COST, SE TYPE 2 (FRAC OF COST/SET)	*	0.	1.	*	________
7	COST/SET OF SE TYPE 3 ($)	*	0.	100000.		________
8	ANNUAL COST, SE TYPE 3 (FRAC OF COST/SET)	*	0.	1.	*	________

* Fixed Limit

LSC, LEVEL 1 (Continued)

SUPPORT EQUIPMENT AND FACILITIES
(Continued)

Support Equipment Costs

		Lower Limit	Upper Limit	Value
9	COST/SET OF SE TYPE 4 ($)	* 0.	100000.	________
10	ANNUAL COST, SE TYPE 4 (FRAC OF COST/SET)	* 0.	1. *	________
11	COST/SET OF SE TYPE 5 ($)	* 0.	100000.	________
12	ANNUAL COST, SE TYPE 5 (FRAC OF COST/SET)	* 0.	1. *	________
13	COST/SET OF SE TYPE 6 ($)	* 0.	100000.	________
14	ANNUAL COST, SE TYPE 6 (FRAC OF COST/SET)	* 0.	1. *	________
15	COST/SET OF SE TYPE 7 ($)	* 0.	100000.	________
16	ANNUAL COST, SE TYPE 7 (FRAC OF COST/SET)	* 0	1. *	________
17	COST/SET OF SE TYPE 8 ($)	* 0	100000.	________
18	ANNUAL COST, SE TYPE 8 (FRAC OF COST/SET)	* 0.	1. *	________
19	COST/SET OF SE TYPE 9 ($)	* 0.	100000.	________
20	ANNUAL COST, SE TYPE 9 (FRAC OF COST/SET)	* 0.	1. *	________
21	COST/SET OF SE TYPE 10 ($)	* 0.	100000.	________
22	ANNUAL COST, SE TYPE 10 (FRAC OF COST/SET)	* 0.	1. *	________
23	COST OF ADDED COMMON SE PER BASE ($)	* 0.	1.00E+6	________
24	COST OF ADDED COMMON SE PER DEPOT ($)	* 0.	1.00E+7	________
25	SYS LEVEL SE, NON-LRU RELATED, BASE ($)	* 0.	100000.	________
26	SYS LEVEL SE, NON-LRU RELATED, DEPOT($)	* 0.	1.00E+6	________
27	COST OF FLIGHT LINE SE PER BASE($)	* 0.	100000.	________
28	SOFTWARE TO UTILIZE EXISTING ATE, ($)	* 0.	1.00E+6	________
29	HARDWARE TO UTILIZE EXISTING ATE, ($)	* 0.	1.00E+6	________

* Fixed Limit

LSC, LEVEL 1 (Continued)

SUPPORT EQUIPMENT AND FACILITIES
(Continued)

Support Equipment Costs
(Continued)

			Lower Limit	Upper Limit	Value
30	COST OF PECULIAR TRAINING EQUIPMENT ($)	*	0.	1.00E+6	______
31	COST OF UNIQUE FACILITIES/BASE ($)	*	0.	1.00E+7	______
32	COST OF UNIQUE DEPOT FACILITIES ($)	*	0.	1.00E+8	______

LOGISTICS OPERATIONS

Technical Orders

4	PAGES OF BASE LEVEL DATA (QTY)	*	0	1000	______
5	PAGES OF DEPOT LEVEL DATA (QTY)	*	0	1000	______

* Fixed Limit

LSC, LEVEL 2

WEAPON SYSTEM DEPLOYMENT, USAGE AND CHARACTERISTICS

Mission Utilization

			Lower Limit	Upper Limit		Value
1	ITEM OPERATING/SYSTEM OPER. TIME RATIO	*	.1	2.		______

Equipment Characteristics

			Lower Limit	Upper Limit		Value
1	ITEM ACQUISITION COST, SPARES ($/UNIT)	*	0.	1.00E+6		______
2	ITEM WEIGHT (LBS)	*	0.	100.		______
3	QUANTITY OF ITEM/NEXT HIGHER ASSEMBLY	*	1	10		______

MAINTENANCE RATES, ACTIVITIES AND COSTS

Reliability and Maintenance Rate Factors

			Lower Limit	Upper Limit		Value
2	MEAN OP TIME BETWEEN CORR MAINT ACT (HRS)		0.	10000.		______
4	INHERENT FAILURE FRAC OF CORR MAINT ACTS	*	0.	1.	*	______
5	INDUCED FAILURE FRAC OF CORR MAINT ACTS	*	0.	1.	*	______

Level of Repair

			Lower Limit	Upper Limit		Value
2	ITEM REMOVALS PER CORR MAINT ACT (FRAC)	*	0.	1.	*	______
5	ITEM REMOVALS NRTS (FRAC)	*	0.	1.	*	______
6	ITEM REMOVALS CONDEMNED (FRAC)	*	0.	1.	*	______

* Fixed Limit

LSC, LEVEL 2 (Continued)

MAINTENANCE RATES, ACTIVITIES AND COSTS
(Continued)

Corrective Action Activities and Costs

		Lower Limit	Upper Limit	Value
2	ACCESS TIME, ON-EQUIP (MHRS)	* 0.	5.	______
4	REPAIR TIME, ON-EQUIP (MHRS)	* 0.	5.	______
5	REMOVE, REPLACE, CHECKOUT, ON-EQUIP (MHRS)	* 0.	5.	______
6	STATE VERIFICATION TIME, BENCH CHECK (MHRS)	* 0.	5.	______
7	REPAIR TIME, OFF-EQUIPMENT (MHRS)	* 0.	20.	______
8	REPAIR TIME, DEPOT (MHRS)	* 0.	20.	______
10	REPAIR OF INDENTURED UNITS, BASE ($/ACT)	* 0.	500.	______
11	REPAIR OF INDENTURED UNITS, DEPOT ($/ACT)	* 0.	500.	______

SUPPORT EQUIPMENT AND FACILITIES

Support Equipment Usage

		Lower Limit	Upper Limit	Value
1	UTILIZATION RATE, SE TYPE 1, BASE LEVEL	* 0.	1. *	______
2	UTILIZATION RATE, SE TYPE 1, DEPOT LEVEL	* 0.	1. *	______
3	UTILIZATION RATE, SE TYPE 2, BASE LEVEL	* 0.	1. *	______
4	UTILIZATION RATE, SE TYPE 2, DEPOT LEVEL	* 0.	1. *	______
5	UTILIZATION RATE, SE TYPE 3, BASE LEVEL	* 0.	1. *	______

* Fixed Limit

LSC, LEVEL 2 (Continued)

SUPPORT EQUIPMENT AND FACILITIES
(Continued)

Support Equipment Usage
(Continued)

		Lower Limit	Upper Limit	Value
6	UTILIZATION RATE, SE TYPE 3, DEPOT LEVEL	* 0.	1. *	______
7	UTILIZATION RATE, SE TYPE 4, BASE LEVEL	* 0.	1. *	______
8	UTILIZATION RATE, SE TYPE 4, DEPOT LEVEL	* 0.	1. *	______
9	UTILIZATION RATE, SE TYPE 5, BASE LEVEL	* 0.	1. *	______
10	UTILIZATION RATE, SE TYPE 5, DEPOT LEVEL	* 0.	1. *	______
11	UTILIZATION RATE, SE TYPE 6, BASE LEVEL	* 0.	1. *	______
12	UTILIZATION RATE, SE TYPE 6, DEPOT LEVEL	* 0.	1. *	______
13	UTILIZATION RATE, SE TYPE 7, BASE LEVEL	* 0.	1. *	______
14	UTILIZATION RATE, SE TYPE 7, DEPOT LEVEL	* 0.	1. *	______
15	UTILIZATION RATE, SE TYPE 8, BASE LEVEL	* 0.	1. *	______
16	UTILIZATION RATE, SE TYPE 8, DEPOT LEVEL	* 0.	1. *	______
17	UTILIZATION RATE, SE TYPE 9, BASE LEVEL	* 0.	1. *	______
18	UTILIZATION RATE, SE TYPE 9, DEPOT LEVEL	* 0.	1. *	______
19	UTILIZATION RATE, SE TYPE 10, BASE LEVEL	* 0.	1. *	______
20	UTILIZATION RATE, SE TYPE 10, DEPOT LEVEL	* 0.	1. *	______

* Fixed Limit

LSC, LEVEL 2 (Continued)

SUPPORT EQUIPMENT AND FACILITIES
(Continued)

Support Equipment Usage
(Continued)

		Lower Limit	Upper Limit	Value
21	DOWNTIME, SE TYPE 1 (FRAC)	* 0.	.99 *	______
22	DOWNTIME, SE TYPE 2 (FRAC)	* 0.	.99 *	______
23	DOWNTIME, SE TYPE 3 (FRAC)	* 0.	.99 *	______
24	DOWNTIME, SE TYPE 4 (FRAC)	* 0.	.99 *	______
25	DOWNTIME, SE TYPE 5 (FRAC)	* 0.	.99 *	______
26	DOWNTIME, SE TYPE 6 (FRAC)	* 0.	.99 *	______
27	DOWNTIME, SE TYPE 7 (FRAC)	* 0.	.99 *	______
28	DOWNTIME, SE TYPE 8 (FRAC)	* 0.	.99 *	______
29	DOWNTIME, SE TYPE 9 (FRAC)	* 0.	.99 *	______
30	DOWNTIME, SE TYPE 10 (FRAC)	* 0.	.99 *	______

LOGISTICS OPERATIONS

Supply Management Factors

		Lower Limit	Upper Limit	Value
1	NEW REPARABLE ASSEMBLIES IN ITEM (QTY)	* 0	100	______
2	NEW CONSUMABLE PARTS IN ITEM (QTY)	* 0	1000	______
3	ADDITIONAL PARTS FOR BASE SUPPLY (QTY)	* 0	1000	______

* Fixed Limit

Appendix D

LSC Model Data Items

Note: (C) = contractor furnished
(S) = government furnished standard value
(P) = government furnished program peculiar value

Appendix D

LSC Model Data Items

Weapon System Variables

1. EBO - Standard established for expected backorders--the expected number of unfilled demands existing at the lowest echelon (bases) at any point in time. (P)

2. IMC - Initial management cost to introduce a new line item of supply (assembly or piece part) into the Air Force inventory. (S = $46.60/item)

3. M - Number of intermediate repair locations (operating bases). (P)

4. MRF - Average manhours per failure to complete off-equipment maintenance records. (S = .24 hours)

5. MRO - Average manhours per failure to complete on-equipment maintenance records. (S = .08 hours)

6. NSYS - Number of systems within the weapon system. (C)

7. OS - Fraction of total force deployed to overseas locations. (P)

8. OST - Weighted average Order and Shipping Time in months. The elapsed time between the initiation of a request for a serviceable item and its receipt by the requesting activity. For CONUS locations, S = 0.394 months (12 days) input as OSTCON. For overseas locations, S = 0.525 months (16 days) input as OSTOS. OST = (OSTCON)(1-OS) + (OSTOS)(OS)

9. PFFH - Peak Force Flying Hours--expected fleet flying hours for one month during the peak usage period. (P)

10. PIUP - Operational service life of the weapon system in years. (Program Inventory Usage Period) (P)

11. PMB - Direct productive manhours per man per year at base level (includes "touch time," transportation time, and setup time). (S = 1728 hours/man/year)

12. PMD - Direct productive manhours per man per year at the depot (includes "touch time," transportation time, and setup time). (S = 1728 hours/man/year)

13. PSC - Average packing and shipping cost to CONUS locations. (S = \$0.59/pound)

14. PSO - Average packing and shipping cost to overseas locations. (S = \$1.22/pound)

15. RMC - Recurring management cost to maintain a line item of supply (assembly or piece part) in the wholesale inventory system. (S = \$104.20/item/year)

16. SA - Annual base supply line item inventory management cost. (S = \$36.[illegible]/item)

17. SR - Average manhours per failure to complete supply transaction records. (S = .25 hours)

18. TD - Average cost per original page of technical documentation. The average acquisition cost of one page of the reproducible source document (does not include reproduction costs). (S = \$220.00/page)

19. TFFH - Expected Total Force Flying Hours over the Program Inventory Usage Period. (P)

20. TR - Average manhours per failure to complete transportation transaction forms. (S = .16 hours)

21. TRB - Annual Turnover rate for base personnel. (S = .134)

22. TRD - Annual turnover rate for depot personnel. (S = .15)

Propulsion System Peculiar Variables

1. ARBUT* - Engine Automatic Resupply and Buildup Time in months. (P)

2. BP* - Base engine repair cycle time in months. (P)

3. CMRI* - Combined Maintenance Removal Interval. Average engine operating hours between removals of the whole engine. (C)

4. CONF - Confidence factor reflecting the probability of satisfying a random demand for a whole engine from serviceable stock to replace a removed engine. (S = 0.90)

5. DP* - Depot engine repair cycle time in months. (P)

6. EOH - Average cost per overhaul of the complete engine at the depot expressed as a fraction of the engine unit cost (EUC) including labor and material consumption. Stockage and repair of reparable engine components (FLUs), considered elsewhere, is not included. (C)

7. ERTS - Return rate for engines. Fraction of removed whole engines which are returned to service by base maintenance. [The complement, (1-ERTS), is the fraction which must be sent to depot for repair/overhaul.] (C)

8. EPA - Number of engines per aircraft. (C)

9. ERMH - Average manhours to remove and replace a whole engine including engine trim and runup time. (C)

10. EUC - Expected Unit Cost of a whole engine. (C)

11. FC - Fuel cost per unit. (S = $0.420/ gallon for JP4; $0.557/ gallon for aviation gas)

12. FR - Fuel consumption rate of one engine in units per flying hour. (C)

13. LS - Number of stockage locations for spare engines. (P)

* Reference AFM 400-1, Volume I, Chapter 7 and Atch 1 for complete description of the Engine Pipeline (Flow Cycle) and use of these terms.

<u>System Variables</u>

1. BCA - Total cost of <u>additional</u> items of common base shop support equipment per base required for the system. (C)

2. BAA - Available work time per man in the base shop in manhours per month. (S = 168 hours)

3. BLR - Base labor rate. (S = $13.03/hour)

4. BMR - Base consumable material consumption rate. Includes minor items of supply (nuts, washers, rags, cleaning fluid, etc.) which are consumed during repair of items. (S = $3.19/hour)

5. BPA - Total cost of peculiar base shop support equipment per base required for the system which is not directly related to repair of specific FLUs or when the quantity required is independent of the anticipated workload (such as overhead cranes and shop fixtures).

6. BRCT - Average Base Repair Cycle Time in months. The elapsed time for a RTS item from removal of the failed item until it is returned to base serviceable stock (less time awaiting parts). For FLUs of the "black box" variety (e.g., avionics LRUs), the repair of which normally consists of removal and replacement of "plug-in" components (SRUs), S = 0.20 months (6 days). For other, nonmodular FLUs, S = 0.33 months (10 days).

7. CS - Cost of software to utilize existing Automatic Test Equipment for the system. (C)

8. DCA - Total cost of <u>additional</u> items of common depot support equipment required for the system. (C)

9. DAA - Available work time per man at the depot in manhours per month. (S = 168 hours)

10. DLR - Depot labor rate. (S = $18.05/hour)

11. DMR - Same as BMR except refers to depot level maintenance. (S = $5.19/hour)

12. DPA - Same as BPA except relates to depot support equipment. (C)

13. DRCT - Weighted average Depot Repair Cycle Time in months. The elapsed time for a NRTS item from removal of the failed item until it is returned to depot serviceable stock. This includes the time required for base-to-depot transportation and handling and the shop flow time within the specialized repair activity required to repair the item. For CONUS locations, S = 1.35 months (41 days) for organic repair, S = 1.84 months (56 days) for contractual repair, input as DRCTC. For overseas locations, S = 1.48 months (45 days) for organic repair, S = 1.97 months (60 days) for contractual repair, input as DRCTO.

$$DRCT = (DRCTC)(1-OS) + (DRCTO)(OS)$$

14. FB - Total cost of new base facilities (including utilities) to be constructed for operation and maintenance of the system, in dollars per base. (C)

15. FD - Total cost of new depot facilities (including utilities) to be constructed for maintenance of the system. (C)

16. FLA - Total cost of peculiar flight-line support equipment and additional items of common flight-line support equipment per base required for the system. (C)

17. H - Number of pages of depot level technical orders and special repair instructions required to maintain the system. (C)

18. IH - Cost of interconnecting hardware to utilize existing Automatic Test Equipment for the system. (C)

19. JJ - Number of pages of organizational and intermediate level technical orders required to maintain the system. (C)

20. N - Number of different FLUs within the system. (C)

21. SMH - Average manhours to perform a scheduled periodic or phased inspection on the system. (C)

22. SMI - Flying hour interval between scheduled periodic or phased inspections on the system. (C)

23. SYSNOUN - Name of the system--up to 60 alphanumeric characters. (C)

24. TCB - Cost of peculiar training per man at base level including instruction and training materials. (C)

25. TCD - Cost of peculiar training per man at the depot including instruction and training materials. (C)

26. TE - Cost of peculiar training equipment required for the system. (C)

27. XSYS - System identification. The assigned five-character alphanumeric Work Unit Code of the system. (C)

FLU Variables

1. BCMH - Average manhours to perform a shop bench check, screening, and fault verification on a removed FLU prior to initiating repair action or condemning the item. (C)

2. BMC - Average cost per failure for a FLU repaired at base level for stockage and repair of lower level assemblies expressed as a fraction of the FLU unit cost (UC). This is the implicit repair disposition cost for a FLU representing labor, material consumption, and stockage/replacement of lower indenture reparable components within the FLU (e.g., shop replaceable units or modules). (C)

3. BMH - Average manhours to perform intermediate-level (base shop) maintenance on a removed FLU including fault isolation, repair, and verification. (C)

4. COND - Fraction of removed FLUs expected to result in condemnation at base level. (C)

5. DMC - Same as BMC except refers to depot repair actions. (C)

6. DMH - Same as BMH except refers to depot-level maintenance. (C)

7. FLUNOUN - Word description or name of the FLU--up to 60 alphanumeric characters. (C)

8. IMH - Average manhours to perform corrective maintenance of the FLU in place or on line without removal including fault isolation, repair, and verification. (C)

9. K - Number of line items of peculiar shop support equipment used in repair of the FLU. (C)

10. MTBF - Mean Time Between Failures in operating hours of the FLU in the operational environment. (C)

11. NRTS - Fraction of removed FLUs expected to be returned to the depot for repair. (C)

12. PA - Number of new "P" coded reparable assemblies within the FLU. (C)

13.	PAMH	- Average manhours expended in place on the installed system for Preparation and Access for the FLU; for example, jacking, unbuttoning, removal of other units and hookup of support equipment. (C)
14.	PP	- Number of new "P" coded consumable items within the FLU. (C)
15.	QPA	- Quantity of like FLUs within the parent system. (Quantity per Application) (C)
16.	RIP	- Fraction of FLU failures which can be repaired in place or on line without removal. (C)
17.	RMH	- Average manhours to fault isolate, remove, and replace the FLU on the installed system and verify restoration of the system to operational status. (C)
18.	RTS	- Fraction of removed FLUs expected to be repaired at base level. (C)
19.	SP	- Number of standard (already stock-numbered) parts within the FLU which will be managed for the first time at bases where this system is deployed. (C)
20.	UC	- Expected unit cost of the FLU at the time of initial provisioning. (C)
21.	UF	- Ratio of operating hours to flying hours for the FLU. (Use Factor) (C)
22.	W	- FLU unit weight in pounds. (C)
23.	XFLU	- FLU identification. The assigned five-character alphanumeric Work Unit Code of the FLU. (C)

Support Equipment Variables

1. BUR - Combined utilization rate for all like items of support equipment—base level. (C)

2. CAB - Cost per unit of peculiar support equipment for the base shop. (C)

3. CAD - Same as CAB except refers to depot support equipment. (C)

4. COB - Annual cost to operate and maintain a unit of support equipment at base level expressed as a fraction of the unit cost (CAB). (C)

5. COD - Same as COB except refers to depot support equipment. (C)

6. DOWN - Fraction of downtime for a unit of support equipment for maintenance and calibration requirements. (C)

7. DUR - Same as BUR except refers to depot support equipment. (C)

8. XSE - SE identification — up to 20 alphanumeric characters. (C)

Vita

Captain Nicholas J. Drobot, USAF, was born in Johnson City, New York in 1949. He received an Associate Degree in Engineering Science from Broome Technical Community College in 1969 and a Bachelor of Science Degree in Aerospace Engineering from the State University of New York at Buffalo in 1971. Commissioned through OTS in 1971, he attended navigator-bombardier training through May 1973. From 1973 to 1978, he served as a navigator/radar navigator in the Strategic Air Command, 416th Bombardment Wing, Griffiss AFB, NY. His next assignment will be to the Air Force Avionics Laboratory as a Logistics Support Cost Program Manager. He is married to the former Darlene J. Cavalieri and they have two children.

Captain Martin H. Johnson, USAF, was born in Lansing, Michigan in 1949. He received a Bachelor of Science Degree in Secondary Education from Central Michigan University in 1971. Commissioned through OTS in 1971, he served as a Command Post Duty Officer and War and Contingency Plans Officer at HQ AFCS from 1972 through 1975. From 1975 to 1978, he served as a ground communications-electronics officer at RAF Lakenheath, England. His next assignment will be to Northern Communications Area (AFCS) as an Engineering and Installation Program Monitor. He is married to the former Alice L. Heilman and they have two children.

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFIT/GSM/SM/79S-5	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A STUDY OF TWO AVIONICS LIFE CYCLE COST MODELS AND THEIR APPLICABILITY IN THE COMMUNICATIONS-ELECTRONICS-METEOROLOGICAL ENVIRONMENT		5. TYPE OF REPORT & PERIOD COVERED M.S. Thesis
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Nicholas J. Drobot, Capt, USAF; Martin H. Johnson, Capt, USAF		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Air Force Institute of Technology (EN) Wright-Patterson AFB, Ohio 45433		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Institute of Technology (EN) Wright-Patterson AFB, Ohio 45433		12. REPORT DATE September 1979
		13. NUMBER OF PAGES 156
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES Approved for public release; IAW AFR 190-17

Joseph P. Hipps, Major, USAF
Director of Information

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Life Cycle Cost
Logistic Support Cost
Cost Models
Communications Cost Modeling
Models

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This study determines the applicability of Life Cycle Cost (LCC)/ Logistic Support Cost (LSC) models in the CEM environment. The study was initiated with a literature search which identified several promising models. The scope of this study addresses two of the models identified (LSC, PRICE) with respect to three Air Force TACAN systems. A methodology is developed to evaluate each model based on the five desirable

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model characteristics: availability of input data, validity, sensitivity, completeness, and documentation. The results presented are also framed within the above model characteristics. The most important model characteristic, validity, is accessed by comparison with an AFCS cost study of NAVAIDs equipment. Based on the methodology, the results indicate that both models are applicable in the present and future CEM environment.